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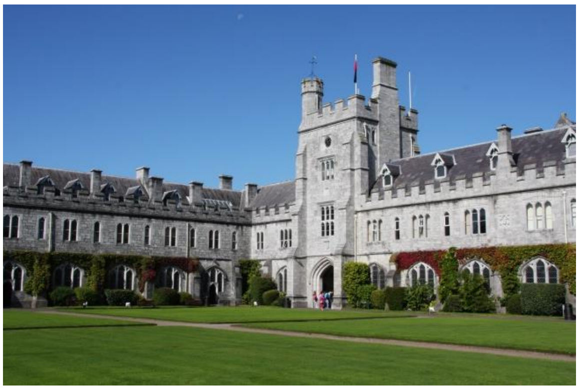

Legal Research Series

Working Paper No. 19

Climate Engineering and International Law: Ignis Fatuus or Last Resort?

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March 2023

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Climate Engineering and International Law: Ignis Fatuus or Last Resort?

*Johannes Mathias Schwaighofer**

Abstract:

Global climate change poses unprecedented threats to humanity. Yet, the human response to this danger seems painfully dull. Measures taken are often not effective enough, or they are not enforced sufficiently. The urgency of the issue has led to the idea of manipulating the planet's climate artificially. Under the term of climate engineering, various methods have been proposed, and while they often promise fast and efficient solutions, most of them are at least risky, if not highly dangerous. However, especially low costs and supposedly strong effects are currently fuelling interest in research and implementation of climate engineering. Strikingly, even though such steps would likely be fatal, legal regulations are rare and dangerously weak.

This paper initially provides an overview of technical aspects of climate engineering. As a second step, indications of international law are analysed. It will be shown that existing legal frameworks, and even general principles of international law, are barely able to regulate climate engineering sufficiently. Especially some rather dangerous climate engineering methods are hardly limited by current international law. The final part of this paper proposes possible policies and principles for the governance of climate engineering. Recommendations include aspects of universality, enforcement and responsibility, and public participation. This chapter is concluded by a brief discussion of human rights and climate justice aspects of climate engineering. In essence, some of the most fundamental human rights may be violated by climate change, but also by climate engineering. This leads to potentially contradictory indications both for and against climate manipulation. Finally, a short analysis of the climate justice context shows that climate engineering could enable especially wealthy states to alter the climate in their favour, while these methods could in return intensify extreme climate conditions for states of the global south that may be unable to use climate engineering themselves.

Keywords: *climate change, climate engineering, geoengineering, international law*

"There is always a well-known solution to every human problem – neat, plausible, and wrong."

– H. L. Mencken[2]

A. INTRODUCTION

Glaciers are diminishing forever, floods and hurricanes wipe out entire villages and cities, food supply is becoming increasingly difficult as crops are destroyed by heat and other extreme weather conditions, more

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[2] Henry Louis Mencken, *Prejudices: Second Series* (Jonathan Cape 1921) 158; Henry Louis Mencken (1880-1956) was an American controversialist and humorous journalist <https://www.britannica.com/biography/H-L-Mencken> accessed 24 March 2023.

and more species lose their battle against extinction, the pole ice is melting rapidly, sea levels rise, and island states have only decades left before the oceans are going to cover their territory entirely. Ecosystems all over the planet are under serious pressure. The worst disasters imaginable are lurking in the twilight of fake news, political inactivity, and populism. Emission reduction pacts and agreements appear to be incapable of stopping climate change.

The end seems near.

But is that it? Is a capitulating "we are sorry, we were not able to stop it" the only message we will be able to leave for the future?

While the situation may seem more and more hopeless, some scientists argue that it is not. Often still a sidenote on the daily news that are dominated by the depressing prospects described above, a potential solution is suggested increasingly loudly: climate engineering. The methods summarised under this term are the antithesis of the exhausting reduction of emissions.[3] They are straightforward, effective, often cheap, and most importantly fast. Some even argue that they may be the only approach that could realistically save us from climate change and its devastating effects.[4] However, while solutions like artificially enabling the oceans to absorb more CO^2 or reflecting excessive solar heat back into outer space may sound intriguingly simple, they are equally dangerous.[5] Without serious research, it is impossible to assess the potential consequences of human-induced climate engineering interventions with natural processes. However, research activities of a relevant scale that would be large enough to produce meaningful findings could themselves be highly dangerous. And as there is only one planet, there is not more than one single shot. One wrong decision, one miscalculation, one single diminutive error could irreversibly doom the entire planet.

Unsurprisingly, this opens enormous legal debates. Yet, international policy making remains painfully silent. Climate engineering discourse is still characterised by legal uncertainty, a lack of seriousness, and a regulatory vacuum. However, erupting questions are as pressing as they are diverse: Would the implementation of certain climate engineering methods be legal under international law? Should it be? Which legal frameworks and instruments are applicable? How can the prevention of potentially dangerous practices be ensured? Some methods may even be operable by an individual wealthy non-state actor. How can international law guarantee effective enforcement in that regard? And finally, who ultimately decides if climate engineering should be implemented? Which institution or forum has the authority, legitimisation, and power to step up and take the fate of humanity into its hand? Subsequentially, it all leads down to even more substantial questions: How far can human domination go? What are the limits of scientific progress? Are we the absolute rulers of nature? And ultimately: how much of a god should the human being be? While the focus of this dissertation does not allow covering these more philosophical aspects of the issue in depth, it is supposed to be a contribution to the ongoing and increasingly heated legal debate that has been gaining momentum in recent years.

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[3] While CO^2 emission reduction is the most important way of limiting the dangers of climate change, the focus of this paper is set on the legal aspects of climate engineering. This focus should not in any way produce the illusion that emission reduction may be less relevant. As it will be shown, the contrary is the case: emission reductions are the only safe way of impeding climate change.

[4] Oliver Milman, 'Can geoengineering fix the climate? Hundreds of scientists say not so fast,' *The Guardian* (25 December 2022) <https://www.theguardian.com/environment/2022/dec/25/can-controversial-geoengineering-fix-climate-crisis> accessed 24 March 2023.

[5] See for example Clive Hamilton, *Earth Masters: The Dawn of the Age of Climate Engineering* (Yale University Press 2013) 20.

First, a brief technical overview of the general concept and some of the most important and representative climate engineering methods shall be provided. This will be followed by an analysis of the legal indications under existing international law. Aspects from various legal areas, ranging from the law of the sea over space law to climate change law will be included. It will be shown that, while several geoengineering approaches would be sufficiently regulated by existing legal frameworks, others (and worryingly some rather dangerous methods in particular) would barely find limitations under *lex lata*. It will be elaborated that even general principles of international law are not able to provide clear implications for the use of geoengineering. In consequence, the final chapter will introduce policy proposals and relevant principles that may be necessary for effective future climate engineering governance. The most important recommendations include matters of universality, enforcement and responsibility, and public participation. The chapter will be concluded by an analysis of climate engineering in the imminently relevant context of human rights and climate justice – aspects that have hardly been dealt with in literature so far.

The entire dissertation is to be seen under the premises of a highly volatile and ongoing scientific process. The legal perspective, just like the more technical part of the debate, is continuously developing.

Unleashing geoengineering to the outermost limits of its full potential may well be the final step – either to humankind's unlimited control of the planet, or to its ultimate doom. The question if climate engineering is the path to salvation or just an ignis fatuus is almost impossible to answer in advance.[6] Policy makers, jurists, scientists, and the entire global community must seek careful steps and collaboration. Only a thoughtful and determined joint effort can limit the risks and ultimately lead to a stable climate and thereby to a safe future for humanity and for the entire planet.

B. GEOENGINEERING – A TECHNICAL OVERVIEW

1. Concept

The idea of taking control over nature is as old as humanity. While the domestication of animals, the use of fire, and working the land for agricultural use can be seen as early first steps, more recent history holds many more examples of human intervention in natural processes – ranging from the construction of dams over large-scale deforestation to building artificial islands and oasis in the desert. However, never in human history has there been any concept that comes close to the large-scale domination geoengineering would mean. Firstly, geoengineering is a rather vague term for a broad concept that includes several different approaches.[7] Usually, these approaches are divided into two groups: Carbon Dioxide Removal (CDR) methods and Solar Radiation Management (SRM).[8] While CDR methods try to eliminate the origin of climate change, which is a rising amount of greenhouse gases in the planet's atmosphere, SRM aims at reducing the temperature rise caused by climate change, mainly by lowering the amount of the sun's heat that enters the atmosphere.[9] CDR methods are in consequence often described to be less harmful and even the highly influential Intergovernmental Panel on Climate Change (IPCC) has explicitly started differentiating the two groups by refraining from the use of "geoengineering" as a term and solely referring to CDR and SRM instead.[10]

[6] *Ignis fatuus* is a Latin term referring to the phenomenon also known as "will-o'-the-wisp". They describe mysterious lights that supposedly occur in bogs and marshes and lead lost wanderers to their death.
[7] Both "climate engineering" and "geoengineering" are common terms in literature. They will be used synonymously in this dissertation.
[8] See Hamilton, *supra note 5*, 20.
[9] *Id*. at 20.
[10] Valérie Masson-Delmotte et al, *Global Warming of 1.5°C* (Intergovernmental Panel on Climate Change 2019) 550.

As mentioned, there are many different methods and approaches, some of them more realistic than others. Some of the most important and representative approaches shall be introduced briefly in this section. Due to the brevity of this dissertation, only a selective overview can be provided here. This does not necessarily mean that the presented methods are the most effective, promising, or dangerous approaches.[11] In order to compare different geoengineering approaches with each other more effectively, the Royal Society introduced four criteria: effectiveness, timeliness, safety, and cost.[12] They will be used throughout this chapter to assess the presented approaches.

(a) Carbon Dioxide Removal Methods (CDR)

Carbon Dioxide Removal Methods "aim to extract excess carbon dioxide from the atmosphere" and to bind them as effectively as possible in a secure location.[13] Generally, it can be said that CDR methods would be slower and more expensive, and that their risks are lower and covered more effectively under existing law.[14]

i. Fertilisation of the oceans

With the deep oceans being an enormous carbon dioxide sequester, one idea is to store emissions in the depth of the seas.[15] One of the most promising ways of achieving this could be based on the artificial acceleration of processes that are in place already. Usually, tiny phytoplankton absorb CO^2 and when they die, they sink to the bottom of the sea and take the carbon with them. In addition, larger species devour phytoplankton, and their excrements and bodies sink to the seabed too. The whole process depends on the size of the phytoplankton population. Phytoplankton mainly need macronutrients like phosphorus, nitrogen and carbon, and micronutrients, particularly iron.[16] As the growth of the population is especially limited by the shortage of iron, the approach aims at increasing the amount of iron artificially and thereby triggering phytoplankton blooms.[17] Although not all of the carbon reaches the seabed as some parts oxide into carbon dioxide again in the course of the process, the idea seems intriguing: higher iron concentrations in the oceans in the past have been linked to ice ages and exceptionally low carbon dioxide concentrations in the atmosphere.[18]

So why has iron fertilisation not been implemented (yet)? The main problem with this approach is, in essence, the unpredictability of its consequences and its rather high costs.[19] It is estimated that iron fertilisation would cost approximately \$500 per ton of CO^2, with an estimated annual removal rate of 1 to 4 gigatons of CO^2. Apart from that, ocean fertilisation is widely seen to be a rather slow and ineffective approach.[20] While costs, effectiveness and timeliness make the approach less attractive already, it should also be mentioned that large-scale eco-system interventions of this kind are utterly risky. Some experts warn that larger

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[11] For a more complete overview and further details about the scientific background see for example Hamilton, *supra note 5*; Masson-Delmotte et al, *supra note 10*; Rob Bellamy & Peter Healey, ''Slippery slope' or 'uphill struggle'? Broadening out expert scenarios of climate engineering research and development' (2018) 83 *Progress in Environmental Science & Policy* 1-10; Mike Hulme, 'Climate change: Climate engineering through stratospheric aerosol injection' (2012) 36(5) *Progress in Physical Geography* 694-705.

[12] The Royal Society, *Geoengineering the climate* (The Royal Society 2009) 6.

[13] See Hamilton, *supra note 5*, 1.

[14] Jesse Reynolds, 'Climate engineering and international law' in Daniel A. Farber & Marjan Peeters (eds*), Climate Change Law Volume I* (Edward Elgar Publishing 2016) 179.

[15] See Hamilton, *supra note 5*, 25.

[16] *Id.*at 27.

[17] *Id.*at 27.

[18] *Id.*at 27.

[19] Brad Allenby, 'Earth system engineering and management' (2000) *IEEE Technology and Society Magazine* 22-23.

[20] Eli Kintisch, 'Technologies' in Michael B. Gerrard & Tracy Hester (eds*), Climate Engineering and the Law* (Cambridge University Press 2018) 48.

phytoplankton populations in certain areas could lead to shrinking populations in other areas, thereby nullifying the effects, or that a resulting stronger algae cover could take away sunlight from corals and other species.[21]

ii. Alkaline spreading and enhanced weathering

Another approach is based on well-known chemical processes: The oceans are absorbing a quarter of anthropogenic emissions from the atmosphere. Combined with seawater, the carbon dioxide creates carbonic acid. As the concentration of greenhouse gases in the atmosphere increases, the higher amount of carbon oxide taken by the oceans increases their acidity.[22] Acidification limits the oceans' capability of absorbing additional CO^2 and affects sea life, especially coral reefs.[23]

Several geoengineering approaches are based on the general idea of taking the oceans' alkalinity back to a normal level in order to enable them to absorb more CO^2.[24] The most straightforward method may be the direct spread of alkaline which should then deacidify the oceans.[25] The basic principle of the approach can be found in natural processes too: In the atmosphere, a reaction between CO^2 and water forms carbonic acid.[26] Mainly distributed through rain, the acid reacts with (weakly basic) rocks to form bicarbonate, which then flow to the ocean and end up forming carbonate sediments on the seabed.[27] Enhanced weathering, another geoengineering approach, aims at accelerating this process and storing "massive quantities of carbon as either dissolved bicarbonate at sea or carbonate compounds on land".[28] As this method is only based on naturally occurring minerals and reactions, it is sometimes considered to be a "soft geoengineering" approach – similar to reforestation, for instance.[29] While the side effects of approaches like enhanced weathering and alkaline spreading are presumably less unpredictable than those of iron fertilisation, there are different boundaries that make an actual implication difficult. The production of both suitable alkaline and grinded rocks, and their distribution would consume a high amount of energy and it would need an immense infrastructure.[30] The annual costs are estimated to be set between $10 and $100 per ton of CO^2 for alkaline spreading, and between $50 and $100 per ton of CO^2 for enhanced weathering.[31] This equals annual costs of up to 100 billion dollars. While "no specific [physical] upper bounds appear in the literature" regarding alkaline spreading, it is suggested that "weathering approaches could remove [a maximum of] 1 gigaton of CO^2 per year between now and 2100".[32] An obvious lack of research makes potential side effects hard to predict and inevitably leads to a certain amount of risk.[33] As so far "only laboratory-scale experiments […] have been done", the National Research Council suggests the implementation of further study.[34]

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[21] See Hamilton, *supra note 5*, 29.
[22] *Id*. at 36.
[23] *Id*. at 36.
[24] *Id*. at 37.
[25] *Id*. at 36-37.
[26] See Kintisch, *supra note 20*, 50.
[27] *Id*. at 50.
[28] *Id*. at 50.
[29] See Kintisch, *supra note 20*, 50.
[30] See Hamilton, *supra note 5*, 40-41.
[31] National Research Council, Division on Earth and Life Studies, *Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration* (National Academies Press 2015) 37-38.
[32] See Kintisch, *supra note 20*, 50-51; See National Research Council, *supra note 31*, 38.
[33] See Hamilton, *supra note 5*, 40.
[34] See National Research Council, *supra note 31*, 55.

iii. Air capture, purification, and storage

Different to the mainly marine based approaches presented before, air capture, purification, and storage mainly relies on an artificially created environment for removing CO^2 from the atmosphere. Suggested methods include direct air capture and storage and bioenergy with carbon capture and storage.[35] "Direct air capture is the technique of scrubbing CO^2 directly from the sky through large facilities."[36] The obtained carbon would then either be stored in a long-term reservoir or, more desirably, processed further to fuels or other products.[37] While the environmental risks of air capture and purification (different to storage) are reasonably low, the approach is estimated to be cost-intensive, and necessary research and engineering before a possible commercialisation could still take decades.[38] Apart from that, it is expected to be highly energy-intensive.[39] The second approach mentioned, bioenergy with carbon capture, uses plants and their photosynthesis to remove CO^2 from the air.[40] The plants grow, and absorb and bind more and more carbon. As the carbonaceous material is then burned or processed to create energy, the CO^2 is released again during the process and can be caught relatively easily.[41] Subsequentially, it can be kept in a long-term storage facility. Just like direct air capture, bioenergy with carbon capture bears only limited immediate environmental risks – the most critical being its excessive use of cropland, that would likely lead to controversial issues like increasing competition with farms and their land and a necessary shift of human diets away from meat.[42] Furthermore, it would be necessary to remove forests to create cropland for suitable fuel stocks.[43] This could have unforeseen and unwanted impacts on greenhouse emissions and whole ecosystems. Apart from that, the effectiveness of the approach is often questioned, with some arguing that the only reasonable aspect of the procedure would be to capture CO^2 immediately after it is emitted.[44]

Probably the most problematic issue that equally affects direct air capture and bioenergy with carbon capture approaches is storage.[45] While some research success has been achieved with injecting CO^2 into basalt formations and letting it mineralise into a harmless solid, worries may be well-founded: "Fracking to obtain natural gas has been shown capable of causing small- to medium-sized earthquakes and has led to allegations of water contamination".[46] It is argued that CO^2 storage could lead to similar issues, and that in consequence utilising the CO^2 would be preferable, yet rather difficult.[47]

(b) Solar Radiation Management Methods (SRM)

"[C]ompared to CDR, […] SRM methods would generally be fast and inexpensive, and pose greater risks. Furthermore, due to […] low expected financial costs, a small number of actors [or even wealthy individuals] could undertake some SRM methods, bypassing the collective action problem that hinders emissions abatement (and CDR) but also presenting the threat of potentially problematic unilateral or non-state

[35] See Kintisch, *supra note 20*, 42-46.
[36] *Id*. at 42.
[37] *Id*. at 42, 46-47.
[38] See Kintisch, *supra note 20*, 42, 44.
[39] See National Research Council, *supra note 31*, 74.
[40] See Kintisch, *supra note 20*, 45.
[41] *Id*. at 45; As the CO^2 is released under controlled, artificial circumstances, it is especially much easier to capture than it would be directly from the air.
[42] *Id*. at 45.
[43] *Id*. at 46.
[44] See Hamilton, *supra note 5*, 46-47.
[45] *Id*. at 46-47.
[46] See Kintisch, *supra note 20*, 47.
[47] *Id*. at 47.

implementation."[48] Apart from that, as SRM methods would not remove greenhouse gases, they would only reduce the "symptom" of global warming, but not other effects like ocean acidification.[49]

Subsequentially, various authoritative bodies have called for SRM research and regulation, among others the Royal Society of London and the US National Academies.[50] A particularly dangerous aspect of SRM methods are termination effects: As they do not lower the amount of greenhouse gases in the atmosphere, the reason for global warming would stay in place even if SRM would be implemented. Subsequentially, once implemented, SRM activities could probably never be ceased again as their termination would lead to a drastic temperature rise most ecosystems would be unable to adapt to.[51] This also leads to a dilemma that is inevitable already: Current air pollution, especially in China and India, has grievous impacts on humans and the environment, but also alleviates temperature rises as it has similar effects SRM methods would have.[52] Consequentially, while growing efforts to improve air quality are positive developments, they may have dangerous impacts on the climate and could potentially make the implementation of SRM methods as a replacement inevitable.[53]

Disturbingly, even though the high risks of SRM methods are well-known, an increased interest in approaches of this kind can be registered recently. The US government developing an ambitious and highly criticised SRM research plan in late 2022 shows how much momentum the idea has gained already and how serious the threat of SRM methods being deployed is.[54] By now, there are start-ups planning to introduce climate engineering, and, as Edward Parson, an environmental law expert at University of California, puts it, "the probability that a nation makes a serious effort on solar geoengineering over the next 30 years is about 90%".[55]

i. Sulphur aerosol spraying

When Mount Pinatubo erupted in 1991, it emitted 14 to 26 megatons of sulphur dioxide aerosols into the stratosphere.[56] The result was a cooling effect of 0.3°C over three years.[57] Sulphur aerosol spraying, probably the SRM approach the has received the most attention so far, is supposed to imitate this process artificially. Proposed techniques include the release from aeroplanes, rockets, naval guns, and even high-altitude balloons and tubes.[58] "Models show that in the stratosphere […] aerosols mix readily, can last for years before removal, and spread about the planet in a matter of weeks."[59] But while "global mean temperatures may be lowered, […] the effect would likely be patchy" as the approach would, according to several climate models, "overcool the tropics and insufficiently cool the Arctic."[60] The approach could be implemented almost immediately, but apart from being only partly sufficient, it is also highly risky.[61] Given the complexity of processes and reactions in the stratosphere, scientists suggest that it is impossible to predict possible

[48] See Reynolds, *supra note 14*, 180.
[49] *Id*. at 180.
[50] *Id*. at 180.
[51] See Hamilton, *supra note 5*, 65-67; see Kintisch, *supra note 20*, 36-37.
[52] Michael C. MacCracken, 'On the possible use of geoengineering to moderate specific climate change impacts' (2009) 4 *Environmental Research Letters* 9.
[53] See Hamilton, *supra note 5*, 70-71.
[54] See Milman, *supra note 4*.
[55] *Id*.
[56] National Research Council, Division on Earth and Life Studies, *Climate Intervention: Reflecting Sunlight to Cool Earth* (National Academies Press 2015) 72-73.
[57] See Kintisch, *supra note 20*, 29.
[58] See Kintisch, *supra note 20*, 30.
[59] *Id*. at 29.
[60] See Kintisch, *supra note 20*, 30.
[61] See Hamilton, *supra note 5*, 61.

outcomes.[62] There might be significant potential for the ozone layer to be damaged, irreversible and tremendous disruptions in rainfall patterns that are vital for food crops and supply, and once implemented there may be no way back due to potentially profound rebound effects that would be triggered by halting the intervention again.[63] Apart from that, uncertainty dominates the debate: while "the Royal Society rates sulphate aerosol spraying highly effective at countering warming", many others doubt the sufficiency of the approach.[64] Concludingly, sulphur aerosol spraying is probably one of the most risky geoengineering techniques. It would be relatively easy to implement, its unpredictable effects could be profound and highly dangerous, and once taken, erroneous steps would potentially be irreversible.

ii. Marine cloud brightening

"Low clouds, particularly over dark ocean surfaces, play a very important role in Earth's energy budget by scattering sunlight back to space that would otherwise reach and warm the surface."[65] Marine cloud brightening effectively aims at enhancing this effect artificially.[66] The idea is to "deliberately introduce additional aerosols to act as cloud condensation nuclei […] changing the properties of clouds in their vicinity to make them more reflective."[67] The idea is not completely unprecedented: Similar effects have been witnessed in the shape of extensive white clouds that form around aerosol pollution from ships' smokestacks.[68] Small-scale research projects carried out from vessels produced promising results. However, the approach faces various issues.

Firstly, rolling out the approach on a large scale would need a vast infrastructure – essentially a large, expensive fleet of specially equipped vessels – which again would emit high amounts of greenhouse gases.[69] Secondly, marine cloud brightening activities would, at least technically, be easy to end. If the vessel fleet would cease its operation, artificially altered clouds would be gone within weeks. However, "the heating suppressed by the intervention would rebound at a much faster rate", an effect that would have disastrous consequences for the entire planet.[70] Therefore, the approach would have to be continued indefinitely once implemented.[71] Thirdly and probably most importantly, the method's impacts on the global climate and other side effects are as unpredictable as they are potentially dangerous. Carrying out cloud brightening activities in one location would change weather patterns in a completely different part of the planet. Vital rainfall could be moved, leaving one area with drought and starvation while another region could be flooded.[72] The aspect of unpredictability, combined with dangerous termination effects, make marine cloud brightening far riskier than it may seem at first sight.

iii. Space-based methods

Several proposals aim at "placing scatterers or reflectors of some kind in space to reduce the amount of sunlight entering Earth's atmosphere."[73] These space-based approaches include various ideas, ranging from

[62] *Id*. at 63.
[63] See Hamilton, *supra note 5*, 63-68; See Kintisch, *supra note 20*, 29.
[64] See Hamilton, *supra note 5*, 62.
[65] See National Research Council, *supra note 56*, 101.
[66] See Kintisch, *supra note 20*, 34.
[67] See National Research Council, *supra note 56*, 102.
[68] See Kintisch, *supra note 20*, 35.
[69] *Id*. at 37.
[70] See Hamilton, *supra note 5*, 55.
[71] See Kintisch, *supra note 20*, 36.
[72] See Hamilton, *supra note 5*, 54-55.
[73] See National Research Council, *supra note 56*, 127.

a large iron mirror over trillions of small spacecrafts or metal discs to a large ring of space dust.[74] The objects would be positioned near the LaGrange 1 point, where the gravitational forces of Earth and Sun essentially counteract each other.[75] While some of those approaches may potentially include possible solutions, they are mainly seen as impractical or even unrealistic, especially due to their excessive costs and technological challenges they would pose.[76]

2. Nature-Based Approaches

While not perfectly in line with the core definition of climate engineering, there are various approaches that could potentially contribute to the protection of the climate, arguably less effectively and fast, yet also less dangerously and invasively. While they do not necessarily share the main legal issues that are brought up by climate engineering, they could potentially be part of a solution and thereby lower the need for the implementation of more dangerous methods. However, to demonstrate that even seemingly harmless approaches need to be carried out carefully, one example will be introduced here briefly.[77]

Plants play an essential role in the procession of CO^2. Especially forests are an important carbon sink and reproduce oxygen. Therefore, reforestation is often seen as particularly desirable for the protection of the climate. Some even describe "ecosystem restoration as one of the most effective solutions at our disposal to mitigate climate change."[78] In general, this is of course true: Re-naturalising destroyed areas is highly desirable and can contribute positively to a more stable climate. However, it should be highlighted that artificially restored forests are not able to support climate mitigation as effectively as their natural counterparts.[79] In some cases, erroneously implemented restoration can even be counterproductive – for example if wrong species of trees are chosen, or if there is a lack of diversity.[80] "Planting forests in areas that currently don't have trees […] can [even] reduce the local availability of water."[81] Consequentially, while certainly not as dangerous as climate engineering methods and although applicable legal hurdles may be limited, even nature-based approaches can have unexpected impacts and should always be carried out with diligence. Most desirably, a focus should be put on the protection and conservation of existing forests. Re-naturalisation should, if possible, be based on natural regeneration. While this may take more time, the result is richer in biodiversity, matches the existing ecosystem, and is also cheaper than artificial reforestation.[82]

C. *LEX LATA* – CURRENT LEGAL REQUIREMENTS

With geoengineering being a very broad concept, various existing regimes can potentially be relevant for the evaluation of its legal perspective. This section aims at presenting the key aspects that can be identified on

[74] *Id*. at 127; See Kintisch, *supra note 20*, 33.
[75] See Kintisch, *supra note 20*, 33.
[76] See National Research Council, *supra note 56*, 128.
[77] As the focus of this dissertation is set on geoengineering and its legal aspects, no further reference to nature-based approaches will be made in the subsequent analysis. However, it should be mentioned that as their implementation is – in contrast to geoengineering activities – usually not harmful at all or at most locally harmful, international law sets hardly any limits for activities of this kind. Relevant indications could potentially be found under the Convention on Biological Diversity.
[78] Jean-Francois Bastin *et al*, 'The global tree restoration potential' (2019) 365 *Science* 76, 78.
[79] Frédéric Amiel, Yann Laurans & Damien Barchiche, 'Should we reforest the Amazon?,' *IDDRI* (4 September 2009) <https://www.iddri.org/en/publications-and-events/blog-post/should-we-reforest-amazon> accessed 24 March 2023.
[80] Ana Belluscio, 'Planting trees can shift water flow' (2009) *Nature* <https://www.nature.com/articles/news.2009.1057> accessed 24 March 2023.
[81] *Id*.
[82] See Amiel *et al*, *supra note 79*.

basis of these regimes and producing possible indications for the regulation of geoengineering.[83] Most importantly, it will be shown that several regimes, while potentially relevant in the context of geoengineering, only tackle the issue rudimentarily (climate change law, space law) while a few others already include a more substantial set of guidelines and rules (Convention on Biological Diversity, law of the sea).[84]

1. General Principles of International Law and Customary International Law

While international law sets rules for a great variety of areas, certain gaps in the legal framework are inevitable – especially in the context of innovation and development. However, this does not mean that geoengineering activities that may not be fully covered by existing legal documents, are not subject to rules and regulation. Wherever black-letter law is not able to fully apply to a certain situation, general principles of international law fill legal gaps.[85] While in practice these principles only apply in cases that are not covered by more specific rules of law, this subsection will be based on the (hypothetical) assumption that there are no further *leges specialis* applicable. It will be shown that the well-established general principles on their own would potentially be able to produce certain indications for the use of geoengineering, but that this would undeniably lead to several issues – most prominently a lack of legal certainty and compliance and enforcement problems.

Probably the most essential principle in this regard is the no transboundary harm rule, which found early expression in the 1941 Trail Smelter Arbitration.[86] It was stated that "no State has the right to use or permit the use of its territory in such a manner as to cause injury by fumes in or to the territory of another or the properties or persons therein, when the case is of serious consequence and the injury is established by clear and convincing evidence."[87] Apart from that, both Principle 21 of the 1972 Stockholm Declaration and Principle 2 of the 1992 Rio Declaration enshrine the principle.[88] They suggest that not only damage occurring in the territory of another state, but also harm to the common goods – mainly the high seas and the atmosphere – falls under its rule.[89] States need to practice due diligence in the case of risk of transboundary harm.[90] One of the most pressing challenges in the context of geoengineering is the relatively low implementation costs of some methods that could inspire wealthy individuals or private entities to take action unilaterally. Consequentially, the fact that states are not only responsible for harm that is directly initiated by themselves, but also for actions taken by non-state actors can be highly relevant. Especially the use of Carbon Dioxide Removal (CDR) methods that can be initiated from the territory of a state can potentially be limited by the no harm principle. On the other hand, most SRM methods do not use state

[83] Some elements of structure and content in this section are based on "Options and Proposals for the International Governance of Geoengineering" by Ralph Bodle et al and on Hagen R. J. Krüger's "Geoengineering und Völkerrecht", two of the most comprehensive legal analyses of climate engineering so far; Ralph Bodle *et al*, 'Options and Proposals for the International Governance of Geoengineering' (2014) 14 *Climate Change*; Hagen R. J. Krüger, *Geoengineering und Völkerrecht* (Mohr Siebeck 2020).
[84] Hagen R. J. Krüger, *Geoengineering und Völkerrecht* (Mohr Siebeck 2020) 252-254.
[85] Ralph Bodle, 'Geoengineering and International Law: The Search for Common Legal Ground' (2010) 46 (2) *Tulsa Law Review* 305, 321.
[86] Trail Smelter Arbitration *(US v Canada)* (1941) 3 RIAA.
[87] *Id.* at 1965.
[88] Stockholm Declaration of the United Nations Conference on the Human Environment (adopted 16 June 1972 UNGA Res 2994/XXVII, 2995/XXII and 2996/XXII) (Stockholm Declaration), Principle 21; Rio Declaration on Environment and Development (adopted 14 June 1992), Principle 2.
[89] Daniel Bodansky, Jutta Brunnée & Lavanya Rajamani, *International Climate Change Law* (Oxford University Press 2017) 40-41.
[90] Jesse Reynolds, 'Climate engineering and international law' in Daniel A. Farber & Marjan Peeters (eds), *Climate Change Law Volume I* (Edward Elgar Publishing 2016) 181.

territory, but are initiated from the high seas or the atmosphere. This may make it more difficult to apply the no transboundary harm principle in cases of that kind.

However, another highly important general principle could – at least at first sight – contain a potential solution: the precautionary principle. It binds countries to be cautious in the face of scientific uncertainty. Geoengineering and especially Solar Radiation Management (SRM) methods are a field of particularly high uncertainty. The precautionary principle even "puts the burden on proponents of climate engineering to prove that it is safe."[91] So, could the precautionary principle be the basis for an effective geoengineering governance approach? Would it possibly even make further debate about regulation measures obsolete? Unfortunately not: although the precautionary principle can provide a certain degree of guidance, it is mainly its general character that ultimately limits its value in this regard. "The problem is that, in the case of geoengineering, failure to take action could also result in irreversible and catastrophic harm due to global warming, so it is unclear which way the principle cuts."[92] As "both climate change and climate engineering present risks of irreversible harm and scientific uncertainty", it is variously asserted that, "a precautionary approach would rule out high-leverage SRM climate engineering methods or that it would call for its research."[93] This leads to a stale-mate situation that makes the precautionary principle's interpretation and application to climate engineering cases difficult, if not impossible.

A third highly important principle is the obligation to cooperate in good faith.[94] It essentially requires states to act with due diligence when taking actions that may affect other countries.[95] Crucial indications taken from the obligation to cooperate could be, regarding research, cooperation and sharing of scientific results, and regarding states that effectively engage in potentially risky geoengineering, duties to notify, to share information, and to consult and cooperate with each other.[96] As these aspects mainly concern the future perspective of geoengineering governance, they will be examined further under the relevant section.[97] It should be mentioned that another source of valuable indications could be the Common but Differentiated Responsibilities principle.[98] As this principle is prominently based in the context of climate change law, this aspect will be discussed in more detail later in this dissertation.[99]

Concludingly, the general principles of international (environmental) law provide several indications for the regulation of geoengineering. Essentially, the precautionary principle binds states to treat situations of scientific uncertainty with appropriate cautiousness and the no transboundary harm principle norms liability even for private actions that originate from a state's territory. Certain indications can also be taken from the obligation to cooperate. However, especially SRM methods are not covered sufficiently by the general principles on their own. Subsequentially, one main conclusion can be taken away from this brief analysis: the application of more specific sources of law, and most likely the introduction of new rules is necessary – particularly in the matter of SRM governance.

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[91] Daniel Bodansky, 'May We Engineer the Climate?' (1996) 33(3) *Climatic Change* 309, 316.
[92] Daniel Bodansky, 'The who, what and wherefore of geoengineering governance' (2013) 121 *Climatic Change* 539, 542.
[93] See Reynolds, *supra note 14*, 185.
[94] Jesse Reynolds, 'International Law' in Michael B. Gerrard & Tracy Hester (eds*), Climate Engineering and the Law* (Cambridge University Press 2018) 127.
[95] *Id*. at 127.
[96] *Id*. at 127.
[97] See D. The Future Perspective.
[98] See Reynolds, *supra note 94*, 124-125.
[99] See 7. Climate Change Law.

2. Law of the Sea

The oceans play a key role in the natural processing and regulation of CO^2. As described above, several climate engineering methods are based on supporting and enhancing the underlying processes in the oceans artificially.[100] While enhanced weathering and alkaline spreading would be marine-based too, ocean fertilisation is receiving particularly growing attention.[101] Although all these interventions can potentially be beneficial, they also pose hardly predictable risks to the delicate balance that the marine ecosystem – and thereby the planet as a whole – is based on. The resulting danger was recognised relatively early in law of the sea legislation. This brief analysis of the main aspects will first look at the more general principles that can be taken from the UN Convention on the Law of the Sea (UNCLOS) and will then examine the London Convention and the London Protocol regulations that address geoengineering more specifically.[102]

The UNCLOS sets out the most fundamental rules for the usage of the oceans and determines the different exclusive and common areas of the seas. Firstly, an important differentiation should be made between research with the intention of gaining knowledge and geoengineering activities that aim directly at the alteration of the climate. The UNCLOS generally supports scientific research.[103] However, it also sets certain limits and states that "marine scientific research shall not unjustifiably interfere with other legitimate uses of the sea" and that states and international organisations are responsible for damage "caused by pollution of the marine environment arising out of marine scientific research undertaken by them or on their behalf."[104] In contrast to research activities, the large-scale implementation of climate engineering is more difficult to legitimise under the law of the sea and both the legal indications and the application of the UNCLOS are rather controversial questions.[105] While subsequentially a precise analysis is difficult to produce, the UNCLOS at least seems to set limitations for the application of marine-based climate engineering methods.

Secondly, the UNCLOS's differentiation between exclusive and common areas of the seas is relevant for the implementation of climate engineering.[106] Effectively, the UNCLOS differentiates four areas: internal waters, territorial sea, exclusive economic zones, and the high seas.[107] The respective location determines the rights and duties of states actors and individuals that intend to carry out scientific research, economic activities, or other tasks. The main determinant for internal waters, territorial sea, and to a certain degree for exclusive economic zones are the respective coastal states and their legislation.[108] Therefore, relevant geoengineering governance would potentially be a matter of national jurisdictions in many cases.[109]

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[100] See especially B. 1. (a) Carbon Dioxide Removal methods.
[101] See Krüger, *supra note 84*, 184.
[102] United Nations Convention on the Law of the Sea (signed 10 December 1982, entered into force 16 November 1994) 1833 UNTS 3 (UNCLOS); Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (adopted 13 November 1972, entered into force 30 August 1975) 1046 UNTS 120 (London Convention); 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (adopted 7 November 1996, entered into force 24 March 2006) 11 UKTS Cm 4078 (London Protocol).
[103] See UNCLOS, *supra note 102*, Articles 87.1, 88, 238-239, 243, 251, 255, 257.
[104] *Id*. at Articles 240(c), 263.3.
[105] See Krüger, *supra note 84*, 193-194; Alexander Proelß & Kerstin Güssow, *Climate Engineering: Instrumente und Institutionen des internationalen Rechts* (Alexander Proelß 2011) 38; Philomene Verlaan, 'Geo-engineering, the Law of the Sea, and Climate Change' (2009) 4 *Carbon & Climate Law Review* 446, 449.
[106] See Krüger, *supra note 84*, 184.
[107] See UNCLOS, *supra note 102*, Articles 2, 3, 8, and 57.
[108] See Krüger, *supra note 84*, 185-188.
[109] *Id.*

Thirdly, based on Article 2.3, Part XII, and especially Article 192-194 of the UNCLOS, one essential aspect is the protection and preservation of the marine environment, which effectively applies to every zone of the seas and thereby also limits states' sovereignty.[110] The protection of the marine environment focusses on the term of "pollution", which is thereby also the most relevant determinant for the protection granted by the UNCLOS.[111] The essential question is if climate engineering methods are to be subsumed under the term of pollution. The UNCLOS itself defines pollution as "introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities."[112] This definition clearly covers certain geoengineering methods. Especially iron fertilisation is based on the introduction of substances (iron) and deliberatively aims at altering natural processes in the oceans, which could likely result in certain deleterious effects.[113] For other methods like enhanced weathering, the assessment is more difficult. In general, pollution is not necessarily limited to marine-based sources only.[114] Measures taken must "deal with all sources of pollution", including "from land-based sources [and] from or through the atmosphere."[115] Some scholars even suggest that this definition could cover SRM methods like sulphur aerosol spraying.[116]

Nevertheless, it should be stressed that the pollution needs to enter the marine system for the term to be applicable.[117] Therefore, the opinion that the protection of the UNCLOS could apply even to orbit-based geoengineering approaches does not appear convincing. Yet, while the question of the respective implications for particular approaches cannot be analysed here in detail, the difficulty to assess certain methods clearly shows a lack of legal certainty regarding climate engineering. As the UNCLOS surely does not cover every possible climate engineering technique and its applicability is highly uncertain in regard to some others, the introduction of additional measures is needed. This could potentially be achieved under the UNCLOS. However, it appears more reasonable under the more general regime of the United Nations Framework Convention on Climate Change (UNFCCC).[118]

While the application and the implications of the UNCLOS are, to a certain degree, a matter of interpretation, geoengineering has been addressed more explicitly under the London Convention and the London Protocol. More specifically, three resolutions regarding the CDR method of ocean fertilisation have been adopted under the London Convention and the London Protocol: Resolution LC-LP.1(2008), Resolution LC-LP.2(2010), and Resolution LP.4(8).[119] The London Protocol is essentially a further development of the London Convention. Therefore, the Protocol supersedes the Convention as between parties to the Protocol that are also parties to the Convention.[120] The universality of both instruments is currently rather limited, with the

[110] See Proelß & Güssow, *supra note* 105, 34-35.
[111] See UNCLOS, *supra note 102*, Article 194.1.
[112] *Id*. at Article 1.1(4).
[113] See also II. A. i. a. Fertilisation of the Oceans.
[114] Jesse Reynolds, 'Climate Engineering Field Research: The Favorable Setting of International Environmental Law' (2014) 5(2) *Washington and Lee Journal of Energy, Climate, and the Environment* 417, 455.
[115] See UNCLOS, *supra note* 102, Article 194.3(a).
[116] Philomene Verlaan, 'Geo-engineering, the Law of the Sea, and Climate Change' (2009) 4 *Carbon & Climate Law Review* 446, 457.
[117] See Reynolds, *supra note 114*, at 455.
[118] United Nations Framework Convention on Climate Change (adopted 9 May 1992, opened for signature from 3 to 14 June 1992) (1992) FCCC/INFORMAL/84 GE.05-62220 (E) 200705 (UNFCCC).
[119] Resolution LC-LP.1(2008) on the Regulation of Ocean Fertilization (31 October 2008) LC 30/16 Annex 6; Resolution LC-LP.2(2010) on the Assessment Framework for Scientific Research Involving Ocean Fertilization (14 October 2010) LC 32/15 Annex 5-6; 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 (18 October 2013) LC 35/15 Annex 4.
[120] See London Protocol, *supra note 102*, Article 23.

London Convention counting 87 and the London Protocol 53 parties, respectively.[121] However, high relevance is given especially to the London Convention as it is seen as part of the "global rules and standards" that the (more universal) UNCLOS refers to in Article 210.6.[122]

In general, the main purpose of the London Convention and the London Protocol is the prevention of marine pollution by dumping.[123] Before the introduction of the three resolutions, the application of the term of "dumping" to ocean fertilisation methods was at least unclear, if not doubtable.[124] However, by explicitly making ocean fertilisation (and other approaches) an issue covered by the London Convention and the London Protocol, the law of the sea is among those fields of law that have produced the most relevant geoengineering regulations so far. In essence, four relevant key aspects summarise the London Convention and London Protocol approach to geoengineering: Firstly, Resolution LC-LP.1(2008) states that ocean fertilisation "should not be allowed".[125] In consequence, large-scale implementations would be virtually impossible. Secondly however, the resolution also sets an exception: "legitimate scientific research".[126] Subsequentially, resolution LC-LP.2(2010) states that "scientific research proposals should be assessed on a case-by-case basis".[127] The basis for this assessment is a specifically drafted Assessment Framework.[128] The assessment process itself consist of an initial assessment, an environmental assessment, the decision making, and a monitoring procedure.[129] The environmental assessment is further divided into problem formulation, site selection and description, exposure assessment, effects assessment, risk characterisation, and risk management.[130] These regulations for ocean fertilisation research show, that the London Convention and the London Protocol have put a solid degree of governance in place already. However, their limited and very specific scope is an issue that impedes their effectiveness regarding geoengineering in general.

Finally, even resolution LC-LP.2(2010) itself stresses the need for a strong orientation towards "global, transparent, and effective control and regulatory mechanism for ocean fertilization activities".[131] While these criteria are indeed crucial for effective governance measures, some scholars associate them with doubts about the general suitability of the London Convention and the London Protocol for geoengineering regulation of that scale.[132] Its limited generality may well be the biggest flaw the law of the sea has in regard to geoengineering. While it covers ocean fertilisation sufficiently well, it is much more difficult to equally apply it to other approaches. To avoid fragmentation and increased legal uncertainty, a more general approach appears desirable.

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121 International Maritime Organization, 'Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter' <https://www.imo.org/en/OurWork/Environment/Pages/London-Convention-Protocol.aspx> accessed 24 March 2023.
122 See Krüger, *supra note 84*, 200-201.
123 See Reynolds, *supra note 94*, 88.
124 See Krüger, *supra note 84*, 211-214.
125 See Resolution LC-LP.1(2008), *supra note 119*, para 8.
126 *Id*. at para 8; see also Resolution LP.4(8), *supra note 119*, annex 4 para 1.3.
127 See Resolution LC-LP.2(2010), *supra note 119*, para 2.
128 Assessment Framework for Scientific Research Involving Ocean Fertilization (14 October 2012) IMO Doc. LC 32/13/Annex 6 (Assessment Framework).
129 See Krüger, *supra note 84*, 228-234.
130 See Assessment Framework, *supra note 128*, paras 1.3.2.1 – 1.3.2.6; See also Krüger, *supra note 84*, 230.
131 See Resolution LC-LP.2(2010), *supra note 119*, para 5.
132 See Krüger, *supra note 84*, 224,

3. Convention on Biological Diversity

Apart from the law of the sea, a second area of international law that is a frontrunner regarding climate engineering regulation is the Convention on Biological Diversity (CBD).[133] It is a multilateral environmental agreement with broad, general commitments.[134] As its main purpose is the conservation of biological diversity, its relevance for climate engineering emerges from the fact that the artificial alteration of the climate "could have positive, negative, or mixed impacts on biological diversity".[135] Read on its own, the CBD enshrines both provisions that can be seen as arguments in favour and others that oppose geoengineering.[136] It should be noted that the CBDs Conferences of the Parties (COPs) have issued four decisions that need to be considered to interpret the CBD correctly in the context of geoengineering. However, as the decisions are influential but non-binding, looking at the CBD on its own first can provide valuable insights. In order to appreciate the arguments enshrined in the CBD itself appropriately, the following paragraphs do not take the decisions into account and focus on a literal interpretation of the CBD instead. Thereafter, the COP decisions will be analysed in more detail.

Article 3 of the CBD restates the no transboundary harm principle and stresses the states' "sovereign right to exploit their own resources pursuant to their own environmental policies"[137] Interestingly, the Preamble of the CBD holds several potentially relevant provisions. Firstly, it is noted that "that where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize such a threat."[138] Without a doubt, climate change poses almost unprecedented threats to biological diversity. Climate engineering would potentially be able to reduce or minimise threats of that kind. However, one of the main arguments against the implementation is the lack of scientific certainty. While this could consequentially be seen as an argument in favour of climate engineering, assumptions of this kind should not be made prematurely. The exact term used in the CBD is "lack of *full* scientific certainty".[139] While this implies that the requirement should not be absolute certainty, not any level of certainty is sufficient. Substantial confidence is still a necessary precondition, considering especially the precautionary principle and its requirement of cautiousness in the face of scientific uncertainty.[140] Climate engineering research, however, is still far from having even reached a level of partial certainty.

Another provision of the CBD Preamble notes that "it is vital to anticipate, prevent and attack the causes of significant reduction or loss of biological diversity at source."[141] The main cause of climate change and the consequent reduction of biological diversity is the emission of greenhouse gases. While SRM methods merely tackle the symptoms of climate change, CDR methods essentially aim at attacking the source of climate change and reducing greenhouse gases, making the provision a possible argument in favour of these approaches.[142] Additionally, the Preamble mentions the "general lack of information and knowledge regarding biological diversity and of the urgent need to develop scientific, technical and institutional

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[133] Convention on Biological Diversity (open for signature 5 June 1992, entered into force 29 December 1993) 1760 UNTS 79 (CBD).
[134] See Reynolds, *supra note 94*, 96.
[135] *Id*. at 96.
[136] *Id*. at 97.
[137] See CBD, *supra note 133*, Article 3; regarding the No Transboundary Harm principle see also A. General Principles of International Law.
[138] *Id.* at Preamble.
[139] *Id.* at Preamble; emphasis in italics added by author.
[140] See also A. General Principles of International Law.
[141] See CBD, *supra note 133*, Preamble.
[142] See also B. Geoengineering – a Technical Overview.

capacities".[143] Unsurprisingly, the lack of knowledge and the underlying needs for research and development are also highly relevant matters in the context of climate engineering.

Finally, Articles 7 of the CBD requires Parties to "identify […] activities which have or are likely to have significant adverse impacts on […] biological diversity, and monitor their effects", and Article 14 stresses the need for environmental impact assessment, public participation, and immediate notification procedures.[144] Another potential argument in favour of geoengineering research can be found under Article 14(e), stating that Parties shall "promote national arrangements for emergency responses to activities or events, whether caused naturally or otherwise, which present a grave and imminent danger".[145]

While the CBD itself does not mention climate engineering explicitly, its COPs have issued four relevant decisions that specifically focus on the matter.[146] Limited on the issue of ocean fertilisation, the first decision was taken in 2008 and essentially requested "to ensure that ocean fertilization activities do not take place until there is an adequate scientific basis on which to justify such activities"[147] Furthermore, it specified the "exception of small scale scientific research studies within coastal waters"[148] Notably, the decision explicitly referred to the London Convention and the London Protocol and the research and regulation that had been introduced under these law of the sea instruments.[149]

Two years later, the scale of the 2008 decision was expanded to include all climate engineering methods.[150] Although the chosen wording is relatively weak ("the Conference of the Parties […] invites Parties and other Governments […] to consider the guidance below"), the 2010 decision increased the general relevance of geoengineering governance under the CBD.[151] Remarkably, the Report of the COP also introduced a tentative climate engineering definition.[152] Interestingly, the definition explicitly excludes "carbon capture and storage from fossil fuels when it captures carbon dioxide before it is released into the atmosphere," an issue that caused criticism and led to the inclusion of a statement that stressed that the mentioned exclusion "is not to be interpreted as an endorsement of carbon capture and storage technologies."[153] Following reports partly changed the definition, added general observations to the debate, expounded various gaps in the understanding of the interchange between climate engineering and biodiversity, and stressed the important need for more intense geoengineering research. The most important feature of these decisions may yet be of symbolic rather than of material nature, "as they represent the only negotiated consensus concerning climate engineering in general […] from representatives of most of the world's states."[154]

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[143] See CBD, *supra note 133*, Preamble.
[144] *Id*. at Article 7(c), Article 14(a)(b)(d).
[145] *Id*. at Article 14(e).
[146] See Reynolds, *supra note 94*, 97.
[147] Report of the Conference of the Parties to the Convention on Biological Diversity on the Work of its Ninth Meeting (2008) Decision IX/16 C.4.
[148] *Id*. at C.4.
[149] *Id*. at C.2.,4.,5; for a more detailed examination of the London Convention and the London Protocol see B. Law of the Sea.
[150] See Reynolds, *supra note 94*, 98.
[151] Report of the Tenth Meeting of the Conference of the Parties to the Convention on Biological Diversity (2010) Decision X/33.8(w).
[152] See Report of the Tenth Meeting of the Conference of the Parties, *supra note 151*, X/33.8(w) footnote 76: "Any technologies that deliberately reduce solar insolation or increase carbon sequestration from the atmosphere on a large-scale that may affect biodiversity (excluding carbon capture and storage from fossil fuels when it captures carbon dioxide before it is released into the atmosphere) should be considered as forms of geo-engineering"; See also Reynolds, *supra note 94*, 98.
[153] See Report of the COP, *supra note 151*, Item 5.6.350.
[154] See Reynolds, *supra note 94*, 98.

In conclusion, it can be summarised that the CBD and especially the COP decisions essentially request states to "ensure that climate engineering activities of a certain type or scale do not take place until explicit criteria are met."[155] Strict limitations are set, and exceptions are only made for small scale research.[156] However, while those features may make the CBD appear to be an appropriate basis for further climate engineering governance, several aspects limit its suitability. Firstly, the CBD and the COP decisions mainly use soft, noncommittal, and vague language and COP decisions are not binding.[157] This is an issue as controversial matters like climate engineering require clearly set-out rules that can provide solid guidance. Secondly, the argument that climate change affects biodiversity, and that geoengineering should therefore be fully regulated by the CBD seems questionable. With climate change being a vast-scale matter that strongly impacts almost every aspect of human life, and thereby almost every area of law, it is at least partly counter-intuitive to merely base the suitability of the CBD as a geoengineering framework on biodiversity being affected by climate change. Following this argument, numerous legal fields and instruments could be similarly appropriate contexts for governance measures. Finally, especially COP decisions are occasionally criticised for a lack of expertise.[158] For instance, the provision that small scale scientific studies on ocean fertilisation should only be carried out within coastal waters is contradictory, as this location would not be scientifically useful.[159] Close following of scientific and legal advice is essential for appropriate climate engineering governance. Consequentially, the CBD does not appear to be fully suitable for regulating the matter on a large-scale.

4. Montreal Protocol

As climate engineering methods like sulphur aerosol spreading potentially alter the atmosphere's chemical composition, regulation could be sought in the 1987 Montreal Protocol, a highly universal treaty that was introduced for the purpose of protecting the ozone layer.[160] However, the Protocol itself is focussed on specified ozone-depleting substances and does not automatically apply to sulphur aerosols, even though they could affect the ozone layer.[161] A potential solution can be found in the Montreal Protocol's parent agreement, the 1985 Vienna Convention.[162] It states the commitment for states to take "appropriate measures […] to protect human health and the environment against adverse effects resulting or likely to result from human activities which modify or are likely to modify the ozone layer."[163] Consequentially, since research to date suggests that [sulphur] aerosols are likely to modify the ozone layer, they fall within the ambit of the ozone regime and could potentially be regulated by the Montreal Protocol."[164] These indications are also valuable for a key question of the following Chapter: is there need for new dedicated geoengineering regulations and if so, which instrument would be a suitable context? While the ozone layer framework could potentially regulate specific aspects like sulphur aerosol spraying, it will be argued that a more general approach (possibly under climate change law/the UNFCCC) would be desirable as fragmentation could

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155 *Id*. at 98.
156 *Id*. at 98.
157 *Id*. at 99.
158 See Reynolds, *supra note 94*, 99.
159 *Id*. at 98
160 Montreal Protocol (adopted 16 September 1987, entered into force 1 January 1989); the Montreal Protocol has been ratified by 198 parties.
161 Daniel Bodansky, *Governing Climate Engineering: Scenarios for* Analysis (Harvard Project on Climate Agreements 2011) 17-18.
162 Vienna Convention for the Protection of the Ozone Layer (adopted 22 March 1985, entered into force 22 September 1988).
163 *Id*. at Article 2(1).
164 See Bodansky, *supra note 161*, 18.

potentially lead to difficulties such as inefficient monitoring, non-compliance, a lack of legal certainty, and evasive effects.[165]

5. Arms Control Law

Historically, one of the first recognitions of the potential risks of artificial engineering can be found in arms control law. In 1974, Richard Nixon and Leonid Brezhnev released a brief joint statement on the dangers of military use of environmental modification.[166] In this statement, they took into consideration that "scientific and technical advances in environmental fields, including climate modification, may open possibilities for using environmental modification techniques for military purposes".[167] Two years later the Convention on the Prohibition of Military or any other Hostile Use of Environmental Modification Techniques (ENMOD) was adopted.[168] It explicitly regulates "environmental modification techniques", which Article II defines as "any technique for changing – through the deliberate manipulation of natural processes – the dynamics, composition or structure of the earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space."[169] It is therefore sometimes suggested that ENMOD would limit climate engineering activities.[170] However, as set out by Article III, ENMOD "shall not hinder the use of environmental modification techniques for peaceful purposes".[171] Consequentially, the convention does not apply to most climate engineering cases.[172]

6. Space Law

While itself a rather undeveloped field of international law, space law shares various touching point with the legal aspects of geoengineering. In general, space law produces legal implications and rules for outer space. As an approximation, outer space is regarded to start at 110 km above sea.[173] Potential SRM methods would either be carried out at a level of less than 80 km, or clearly above 110 km, which would therefore fall within the scope of space law.[174] While approaches that would be deployed from outer space are widely seen as rather unlikely options, the proximity between the telos of geoengineering regulation and space law, respectively, makes a brief analysis highly relevant.[175]

None of the treaties of international space law deals with climate engineering specifically. Nevertheless, the two instruments that would potentially be applicable are the Outer Space Treaty and the Space Liability Convention.[176] Generally spoken, space law is an open and highly flexible field. Article III of the Outer Space

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[165] Ralph Bodle *et al*, 'Options and Proposals for the International Governance of Geoengineering' (2014) 14 *Climate Change*, 175.

[166] Richard Nixon: President of the United States of America 1969-74; Leonid Brezhnev: General Secretary of the Communist Party of the Soviet Union 1964-82.

[167] Statement on Dangers of Military Use of Environmental Modification, released 3 July 1974, available online <https://ns.clementspapers.org/clementsns/pdf/34034> accessed 24 March 2023.

[168] Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (adopted 10 December 1976, entered into force 05 October 1978) 189 UNTS 1108 (ENMOD).

[169] *Id*. at Article II.

[170] See Bodansky, *supra note 161*, 14-15.

[171] See ENMOD, *supra note 168*, Article III.

[172] See Bodansky, *supra note 161*, 15.

[173] See Bodle et al, *supra note 165*, 81.

[174] *Id*. at 81.

[175] See Krüger, *supra note 84*, 100.

[176] See Proelß & Güssow, *supra note 110*, 13; Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (adopted 19 December 1966, entered into force 10 October 1967) 610 UNTS 205 (Outer Space Treaty); Convention on International Liability for Damage Caused by Space Objects (adopted 29 November 1971, entered into force 1 September 1972) 961 UNTS 187 (Space Liability Convention).

Treaty explicitly states that activities in outer space shall be carried out "in accordance with international law".[177] Thereby, space law itself deliberatively draws from other international law to fill legal gaps. While other regulatory frameworks (for example the formerly mentioned ENMOD) have a rather restrictive character and contain explicit decisions against certain methods, the general approach followed in space law is in favour of the use of outer space.[178] This is essentially also the case for space-based geoengineering methods.[179] In practice, a potential regulatory approach could be the introduction of political principles by the UN General Assembly, based on the preparation by the UN Committee on the Peaceful Uses of Outer Space (COPUOS).[180] This would be a typical procedure in the context of space law and would potentially be effective enough to regulate specific research or implementation projects sufficiently.[181] However, it must be acknowledged that climate engineering would normally mainly affect planet earth, and only to a lesser degree outer space. It should therefore be noted that, while space law does share a number of similarities with the matters of geoengineering, it is probably not the right environment to introduce specific regulatory measures in.[182] A more desirable approach would be the regulation under more general regimes such as the UNFCCC.[183] Where needed, those regulations could then still find their way into space law matters on basis of Article III of the Outer Space Treaty.[184]

7. Climate Change Law

As geoengineering aims at combating climate change by artificially altering the climate, climate change law is probably the most obvious area of law that could provide guidance and regulation. In consequence, it appears not very intuitive that the most fundamental document of climate change law, the UNFCCC, covers the issue of geoengineering at most sporadically.[185] However, a number of indications can be drawn from existing international law. Apart from that, the UNFCCC and the Paris Agreement – both treaties with highly universal participation – are often argued to be the most desirable foundation for the introduction of climate engineering governance measures.[186] The focus of this section will be put on some of the most relevant general guidelines and indications of the framework as an in-depth analysis of all potentially relevant aspects would exceed the scale of this piece.

A reasonable starting point for analysis is the general objective of the UNFCCC, which is "to achieve […] stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system"[187] At first sight, CDR methods appear to be ideal for pursuing that aim. They aim at preventing serious changes of the climate by reducing the amount of CO^2 in the atmosphere and could therefore be argued to be a solution that is as legitimate as the prevention of greenhouse gas emissions. However, CDR methods are only able to store the captured or bound carbon dioxide temporarily.[188] Consequentially, while they could be able to contribute to the stabilisation of the

[177] See Outer Space Treaty, *supra note 176*, Article III.
[178] See Krüger, *supra note 84*, 122.
[179] *Id*. at 122.
[180] *Id*. at 122.
[181] *Id*. at 122.
[182] *Id*. at 122.
[183] Karen N. Scott, 'International law in the Anthropocene: responding to the geoengineering challenge' (2013) 34(2) *Michigan Journal of International Law* 309, 356.
[184] See Krüger, *supra note 84*, 122.
[185] Ralph Bodle *et al*, 'Geoengineering in Relation to the Convention on Biological Diversity: Technical and Regulatory Matters. Part II: The Regulatory Framework for Climate-Related Geoengineering Relevant to the Convention on Biological Diversity' (2012) 66 *CBD Technical Series* 127.
[186] See Scott, *supra note 183*, 356.
[187] See UNFCCC, *supra note 118*, Article 2.
[188] See Krüger, *supra note 84*, 340.

climate, they should not be seen as an equally desirable option. The reduction of emissions is necessarily the main approach that should be pursued. Regarding SRM methods, an essential question is their legitimacy under the UNFCCC, specifically under Article 2. As SRM methods do not influence the CO^2 concentration in the atmosphere at all, it could be argued that they are not legitimate approaches under the UNFCCC. Yet, some arguments can be found in favour of SRM approaches. For instance, it is sometimes argued that they would potentially be able to change the meaning of the CO^2 concentration requirement "at a level that would prevent dangerous anthropogenic interference with the climate system" or that their implementation would avoid dangerous tipping points like the destruction of the permafrost and that they would therefore be within the scope of Article 2.[189] However, the more convincing interpretation is that Article 2 requires an immediate link between the prevention of danger and the stabilisation of CO^2 concentration.[190] As SRM methods merely tackle the symptoms but not the cause of climate change, they do not seem to be in line with the direction determined by the UNFCCC.

As mentioned before, an essential foundation of climate change law is the Common but Differentiated Responsibilities principle.[191] Introduced under the UNFCCC and affirmed by both the Kyoto Protocol and the Paris Agreement, it essentially states that, while sovereign states are equal under international law, their environmental responsibilities diverge depending on their possibilities.[192] As suggested by Jesse Reynolds, "the principle […] implies that wealthier countries should carry most of the burdens of researching, developing, and implementing (if appropriate) climate engineering."[193] In addition, he mentions that the UNFCCC calling on states to cooperate in research concerning "various response strategies" and the Paris Agreement noting "the importance of technology for the implementation of mitigation and adaptation actions", committing to "cooperative action on technology development and transfer", and the ambitious aims set by climate change law in general might actually point towards climate engineering.[194] Interestingly, the implementation of CDR methods – more specifically bioenergy with carbon capture and storage – is even included in representative concentration pathways used by the Intergovernmental Panel on Climate Change.[195]

The climate change law indications for SRM methods are less clear.[196] As the Paris Agreement's core determinant is the temperature rise, SRM techniques would potentially be acceptable approaches to reach the set target values, even though they do not impact the concentration of CO^2 in the atmosphere.[197] "Notably, the UNFCCC does not prohibit or exclude any means to reduce climate risks."[198] It could be argued that the term of "dangerous anthropogenic interference with the climate system" could apply to SRM methods.[199] However, some scholars suggest that SRM methods would shift the meaning of "dangerous" and

[189] Matthias Honegger, Kushini Sugathapala & Axel Michaelowa, 'Tackling Climate Change: Where Can the Generic Framework Be Located?' (2013) 7(2) *Carbon & Climate Law Review* 125, 131-132; See UNFCCC, *supra note 118*, Article 2.
[190] See Krüger, *supra note 84*, 340.
[191] See Reynolds, *supra note 94*, 124.
[192] *Id*. at 124-125.
[193] *Id*. at 124-125.
[194] *Id*. at 65, 125; See UNFCCC, *supra note 118*, Article 4.1(g); Paris Agreement under the United Nations Framework Convention on Climate Change (adopted 22 April 2016, entered into force 4 November 2016) (Paris Agreement) Article 10.2.
[195] Intergovernmental Panel on Climate Change, *Climate Change 2014: Mitigation of Climate Change: Working Group III Contribution to the IPCC Fifth Assessment Report* (Cambridge University Press 2015) 485; Representative concentration pathways are possible scenarios set out by the Panel.
[196] See Reynolds, *supra note 114*, 437.
[197] See Paris Agreement, *supra note 194*, Article 2.1(a).
[198] See Reynolds, *supra note 94*, 66.
[199] See UNFCCC, *supra note 118*, Article 2.

could therefore be legal, if not desirable, under the UNFCCC.[200] While this argument does not seem fully convincing – especially considering that the UNFCCC explicitly focusses on the "stabilization of greenhouse gas concentrations" – the debate is a manifestation of insufficient legal certainty.[201] This leads to the final aspect of geoengineering in the context of climate change law: As it is often seen to be "necessary that a legal framework be adopted to address geoengineering as a whole", climate change law – especially the UNFCCC – is arguably the most suitable framework for the introduction of ambitious climate engineering governance measures.[202] Sufficient regulations of this kind would essentially require clearer guidance that explicitly refers to climate engineering. More detailed aspects that should be included will be proposed below.

D. THE FUTURE PERSPECTIVE

It has been shown in the previous section that geoengineering potentially affects a broad variety of different (legal) areas. However, as stated by Daniel Bodansky in one of the earliest pieces that analyse geoengineering in the legal context, "international law has relatively little specific to say about climate engineering."[203] Although the sentence is more than 25 years old, it is still painfully accurate: even though a number of existing legal rules may in theory cover geoengineering, most of these rules were not developed with the artificial alteration of the climate in mind.[204] This has led to the claim of a possible need for "science-based, global, transparent and effective control and regulatory mechanisms for climate-related geoengineering".[205] The COP has noted that "such mechanisms may be most necessary for those geoengineering activities that have a potential to cause significant adverse transboundary effects, and those deployed in areas beyond national jurisdiction and the atmosphere".[206] Jesse Reynolds suggests that Carbon Dioxide Removal (CDR) methods, in contrast with Solar Radiation Management (SRM) methods, "do not present novel challenges for international regulation".[207] He argues that, "[b]ecause their environmental risks would mostly be local, they are primarily the domain of national law."[208] Apart from that, approaches that could potentially affect the high seas, like for example iron fertilisation, are mainly a matter of the mechanisms of the law of the sea.[209] However, while this leads to the conclusion that the focus of new regulations should be put on SRM methods, CDR methods should not be left out of the debate. Some of them have a potentially harmful side effects and may bring up various social and ethical questions.[210]

Meanwhile, regarding SRM methods, some scholars even propose the introduction of an international non-use agreement.[211] Others call for new binding and highly specific rules with near-universal participation, possibly through amendments to the UNFCCC.[212] On the other hand, some proposals point towards more

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[200] See Honegger *et al*, *supra note 189*, 130.
[201] See UNFCCC, *supra note 118*, Article 2; See Krüger, *supra note 84*, 342.
[202] Michael B. Gerrard & Dionysia-Theodora Avgerinopoulou, 'Development and the future of climate change law' in David Leary and Balakrishna Pisupati (eds), *The future of international environmental law* (United Nations University Press 2012) 163.
[203] See Bodansky, *supra note 91*, 316; see also Bodansky, *supra note 161*.
[204] See Bodansky, *supra note 91*, 316.
[205] UNEP 'Climate-related geoengineering' in 'Decision adopted by the conference of the parties to the convention on biological diversity at its eleventh meeting' (5 December 2012) UN Doc UNEP/CBD/COP/DEC/XI/20, para 8.
[206] *Id*. at para 8.
[207] See Reynolds, *supra note 90*, 183.
[208] *Id*. at 183.
[209] *Id*. at 183.
[210] *Id*. at 180; see also B.1.(a) Carbon Dioxide Removal.
[211] Frank Biermann *et al*, 'Solar geoengineering: The case for an international non-use agreement' (2022) 13(3) *Wiley Interdisciplinary Reviews: Climate Change* 4-6.
[212] See Bodle *et al*, *supra note 165*, 201.

general, procedural, and non-binding rules.[213] They suggest that detailed regulations would not be able to adapt to new technologies at an appropriate pace. Apart from that, they warn that low participation rates may impede successful governance as the political desire for new international environmental agreements is low.[214] In essence however, while certain activities should be regulated on a national or regional level, it is relatively clear that the introduction of new, international measures will be necessary. This section aims at examining relevant aspects of the regulation of geoengineering more closely and is meant to contribute to the ongoing international debate on their potential use. First, several objectives, which should be included within a geoengineering governance approach will be proposed. Brief notice shall then be taken of the question of the most desirable governance forum and structure for new regulation rules. The final part of this section will analyse the issue of climate engineering in a human rights and climate justice context.

1. Relevant Governance Principles, Objectives, and Criteria

The following proposals combine ideas and inputs from various sources. Among others, they draw from the Oxford Principles, one of the most ambitious geoengineering-related governance proposal attempts so far.[215] While the presented objectives could in practice be introduced in a variety of different forums, it can be assumed that they could work most effectively if enshrined in one dedicated framework. This would enable norms to refer to each other in a more balanced and elaborate way, which would make the introduced framework more effective and well-rounded. The objectives will be structured into three sections: *Universality and Enforceability*, *Subsidiarity and Liability*, and *Research, Flexibility, and Public Participation*. It should be highlighted that, while the objectives proposed in this dissertation can be crucial points for the regulation of the geoengineering, a potential (international) agreement should not be limited to them.

(a) Maximising Effectiveness – Universality and Enforceability

Both climate change and geoengineering are global phenomena. Therefore, a high degree of universality is important to regulate geoengineering effectively. This is crucial in two separate ways: firstly, regulatory measures need to be binding for as many potential actors as possible. This includes states, but also non-governmental organisations, companies, and even individuals. Secondly, geoengineering is a multi-dimensional term, with possible approaches ranging from CDR methods like iron fertilisation of the oceans, that currently mainly falls under the rule of the London Convention and the London Protocol, to SRM approaches like sulphur aerosol spraying, which could potentially be subject to regulation by ozone layer protection regimes.[216] This multi-dimensional character manifests itself in the (partly) existing system of fragmented legal requirements that need to be sought in various fields and forums of international law. This necessarily leads to more complicated processes and a lack of clarity and legal certainty. Subsequentially, a more universal legal approach should be chosen for any forum that is meant to cover geoengineering appropriately.

Examples for international law forums that fulfil the requirement of universality can be found in an area that could become highly relevant for geoengineering governance: environmental and climate change law. The Montreal Protocol, which is focussed on the protection of the ozone layer, is often praised as one of the most successful international law treaties.[217] The subject of the Montreal Protocol is arguably less complex than

[213] See Reynolds, supra note 90, 184.
[214] *Id*. at 184.
[215] Steve Rayner *et al*, 'The Oxford Principles' (2013) 121 *Climatic Change* 499.
[216] Hagen R. J. Krüger, *supra note 84*, 141; see London Convention, *supra note 102*; see London Protocol, *supra note 102*; see also C. *Lex Lata* – Current Legal Requirements.
[217] Steinar Andresen, 'Effectiveness' in Lavanya Rajamani & Jacqueline Peel (eds*), The Oxford Handbook of International Environmental Law* (Oxford University Press USA 2021) 997-998.

climate change or the regulation of geoengineering.[218] However, it has been ratified by 197 state parties, which makes it a highly universal treaty.[219] Another relevant example is the Paris Agreement and the UNFCCC. While the earlier Kyoto Protocol was signed and ratified by only a fraction of the global community, the Paris Agreement aims at binding virtually every country in the world and has been signed by 195 and ratified by 193 countries.[220] Although it could subsequentially be argued that climate change law has brought forward universal instruments, it needs to be considered that the regulation of geoengineering includes an additional aspect that has not been a focus of climate change law so far: technology and science. Although geoengineering is highly relevant in the context of climate change, its different telos and direction make comparison with existing climate change regimes difficult. It must in consequence be acknowledged that it may be more difficult to get similarly high approval rates for an instrument of that kind.

In addition, universality is closely connected with compliance issues: even universal ratification is worthless if actors do not comply with the agreement. For instance, although the Outer Space Treaty and other space law agreements set a liability for "launching of an object into outer space", states act highly carelessly and recently, even one of the richest individuals on the planet launched an old car into space, presumably for reasons of publicity.[221] A lack of compliance by states and reckless actions carried out by non-state actors are both issues that could potentially arise in the context of geoengineering, particularly as a broad international consensus in this controversial matter may be difficult to reach. It is worth mentioning that especially the highly universal climate change law treaties are frequently under critique for lacking compliance.[222] Measures that are supposed to work satisfyingly require an elaborate balance between universality and enforceability. Especially traditional environmental law enforcement is often heavily dependent on measures taken by state parties. This has led to unfortunate situations in the past. Probably most notoriously, enforcement actions could likely have been taken in the case of the former USSR and the Chernobyl accident.[223] However, nothing was done due to diplomatic reasons, which leads to the assumption that enforcement should not depend solely on the action taken by states.[224] An approach that is seen as more effective can be found in the Montreal Protocol, which has led to a reduction of the use of the ozone-depleting chemicals by more than 95% by 2010.[225] The main elements of this success are the close accordance with scientific advice and a system of incentives, that made it more attractive for the global South to opt in.[226] Again, it needs to be mentioned that geoengineering is a more complex issue than the protection of the ozone layer. However, the elements of success can and should be applied to the introduction of any geoengineering regulatory instruments as well. This is essential, as in the context of geoengineering lack of compliance could be a particularly dangerous flaw – be it because of the immense pressure on states that climate change induced

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[218] *Id*. at 997-998.

[219] UN Environment Programme, 'Country profiles' (*UN Environment Programme*) <https://ozone.unep.org/countries> accessed 24 March 2023.

[220] Daniel Bodansky, 'The Paris Climate Change Agreement: A New Hope?' (2016) 110 *The American Journal of International Law* 288, 290.

[221] See Outer Space Treaty, *supra note 176*, Article VII; Edward Helmore, 'Chinese rocket's chaotic fall to Earth highlights problem of space junk,' *The Guardian* (8 May 2021) <https://www.theguardian.com/science/2021/may/08/chinese-rocket-space-junk-long-march-5gb> accessed 24 March 2023; Jackie Wattles, 'Elon Musk launched his own Tesla roadster to space four years ago. Where is it now?,' *CNN Business* (8 February 2022) <https://edition.cnn.com/2022/02/08/tech/spacex-tesla-roadster-falcon-heavy-anniversary-scn/index.html> accessed 24 March 2023.

[222] Alan E. Boyle, 'Saving the World? Implementation and Enforcement of International Environmental Law through International Institutions' (1991) 3(2) *Journal of Environmental Law* 229, 229-230.

[223] Mary Ellen O'Connell, 'Enforcement and the Success of International Environmental Law' (1995-1996) 3 *Indiana Journal of Global Legal Studies* 47, 48.

[224] Thilo Marauhn, 'The State' in Lavanya Rajamani & Jacqueline Peel (eds*), The Oxford Handbook of International Environmental Law* (Oxford University Press USA 2021) 621.

[225] See Andresen, *supra note 217*, 997.

[226] *Id.* at 997.

hazards could build up in the future, or because private individuals may not fully be bound by an (international) legal framework, but could still interfere with the global climate. Daniel Bodansky, acknowledging the issues mentioned, proposes a number of factors that the level of compliance (or "self-implementation") depends on – specifically, he mentions legal form, precision, legitimacy, incentives to violate, and the ability to comply. [227]

Regarding legal form, it can be assumed that "binding agreements have a greater influence on state behavior than non-binding (soft law) instruments".[228] However, it is also worth mentioning that "soft law rules can also sometimes be effective" and that "in some circumstances, non-binding instruments may be more effective than binding ones, by allowing states to adopt clear and ambitious commitments."[229] In the context of geoengineering, a system of both binding and non-binding rules could be desirable. Effectively, the Paris Agreement approach or the way EU directives set certain targets, but still leave certain spaces up to the member states, could serve as examples. Combining these ways of operation might be an effective basis for geoengineering governance. Especially target values and central principles should be binding, while other provisions could follow a non-binding approach that mainly relies on further specification by state parties.

Another highly relevant aspect is precision. "Precise rules provide greater guidance for behavior than general rules, which can be interpreted in self-serving ways."[230] However, the existing legal rules and principles that are applicable to geoengineering are mostly very general and do not provide sufficiently precise guidance. The lack of precision can even result in paradoxical situations. For example, it can become unclear what the precautionary principle, which binds countries to act cautiously when confronted with cases of scientific uncertainty in the context of environmental law, requires states to do. In this case, the problem is that, while geoengineering and its consequences are connected with a high amount of uncertainty, "failure to take action could also result in irreversible and catastrophic harm due to global warming, so it is unclear which way the principle cuts."[231] It must be acknowledged that more vague instruments have higher chances of being adopted by states. Yet, if provisions of a geoengineering agreement are not sufficiently clear, they may even create additional danger by legitimising actions that they were meant to regulate and prevent. Especially agreements that seek both a high degree of universality and strong compliance rates are often insufficiently precise as especially controversial and therefore particularly relevant aspects may have been removed during the struggle for compromise and consensus. For example, the question of germline editing under human rights law is debated controversially on the international level.[232] The 1997 UNESCO Universal Declaration on the Human Genome and Human Rights, while arguably the most important international instrument in the field of human genetics and supported by a broad consensus when adopted, fails to cover the (highly relevant) issue of germline editing appropriately.[233] This kind of flaw could also impede efforts for appropriate climate engineering regulation, which makes the following factor, legitimacy, even more relevant.

Legitimacy refers to the relevance of the process that leads to the introduction of regulatory measures. It is assumed that states will rather comply with an obligation that has been introduced in a procedure that they see as inclusive and participatory.[234]

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[227] See Bodansky, *supra note 92*, 542-543.
[228] *Id*. at 542.
[229] *Id*. at 542.
[230] See Bodansky, *supra note 92*, 542.
[231] *Id*. at 542.
[232] Rumiana Yotova, 'Regulating Genome Editing Under International Human Rights Law' (2020) 69(3) *International and Comparative Law Quarterly* 653, 671; "germline editing" refers to genetic alterations that edit an individual's genome. The manipulation of the genome is heritable.
[233] *Id*. at 671-672.
[234] See Bodansky, *supra note 92*, 543.

Another aspect Bodansky includes in his essay are incentives to violate. As he puts it, "[t]he greater the costs imposed by a legal rule, the greater the incentive for a state to violate it. For this reason, procedural rules that impose few costs […] may be more effective than a complete prohibition on geoengineering activities, which a state would have a huge incentive to violate if it faced catastrophic climate change."[235]

Finally, the ability to comply is an important factor in the assessment of compliance and enforcement. Although intentional non-compliance does exist, the majority of non-compliance cases are a result of insufficient funding, a lack of resources, internal political problems, or other reasons that cannot be fully controlled.[236] These cases of good faith non-compliance do not necessarily imply insufficient enforcement.[237] To give an example, "a prohibition on geoengineering activities by private actors might be difficult for a state to enforce if it has limited administrative capacity to monitor and control private conduct."[238] States that fail to comply with regulations due to a lack of resources or limited capacity need to be supported appropriately.

(b) Solving Problems – Subsidiarity and Liability

The issues described above lead to the essential aspect of subsidiarity. As mentioned above, it is difficult to effectively combine universality, compliance, and precision on an international level. This means that local implementation plays a key role.[239] International law gains effectiveness if it is transferred into national or regional law. Apart from that, the legislative process of smaller units allows more rapid adaptation and better enforceability.[240] Notably, probably the earliest (sub-national) regulation attempt that is exclusively dedicated to geoengineering was introduced in the US state of Rhode Island in 2014.[241]

Especially many CDR methods that often pose more regional risks could be regulated effectively on a local level. As mentioned above, the most desirable process would be based on binding guiding principles and target values that could be produced on the international level and then transported into more specific, adaptable, and flexible national legislation. This would include various advantages: not all international regulations would necessarily have to be binding and since they would mainly contain general guidelines, most of them would not need to be highly specific, which would make it less difficult to reach consensus among agreement parties. This approach would take the earlier mentioned reservation towards highly technical and specific regulations into account, yet it would also pay tribute to the (equally well-founded) proposal of some scholars that suggest that binding and detailed rules will be necessary.[242] At the same time, it would be possible to react faster to new scientific findings and technology development.

Doubtlessly, this mainly applies to the regulation of CDR methods. It is necessary to stress that, considering the global impact of virtually all SRM methods, specific and restrictive governance measures for these approaches would need to be introduced on the international level. However, they could be accompanied by related local legislation, which would especially improve their enforceability.

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[235] See Bodansky, *supra note 92*, 543.
[236] Markus Ehrmann, 'Procedures of Compliance Control in International Environmental Treaties' (2002) 13(2) *COJIELP* 442.
[237] Ronald B. Mitchell, 'Compliance Theory: Compliance, Effectiveness, and Behaviour Change in International Environmental Law' in Daniel Bodansky, Jutta Brunnée, & Ellen Hey (eds), *The Oxford Handbook of International Environmental Law [online]* (Oxford University Press 2008) 2.
[238] See Bodansky, *supra note 92*, 543.
[239] See Reynolds, *supra note 90*, 186.
[240] *Id*. at 186.
[241] Rhode Island H7655; Rhode Island H5480 (2015); Rhode Island H7578 (2016).
[242] See Reynolds, *supra note 90,* 184.

Notably, while many geoengineering techniques have potentially grievous impacts on the entire planet, some of them – especially SRM methods – could be carried out relatively effortlessly, potentially even by wealthy individuals.[243] However, international legal obligations do usually not directly bind non-state actors.[244] As proposed above, states could solve the issue by incorporating international legal obligations into their national orders and thereby making them binding for non-state actors.[245] An institutionalised variant of this procedure can be found in European Union law: EU directives. According to Article 288 of the Treaty on the Functioning of the European Union they "shall be binding, as to the result to be achieved, upon each Member State to which it is addressed, but shall leave to the national authorities the choice of form and methods."[246] Effectively, the Member States are bound to implement appropriate measures within their jurisdictions, which genuinely bind individuals and non-state actors in general. Another approach can be found in the context of various national jurisdictions: the indirect horizontal effect, or "mittelbare Drittwirkung" in German-speaking jurisdictions.[247] This effect describes the principle that, while for instance fundamental rights do not directly bind non-state actors, they still have an indirect effect on those actors. More specifically, fundamental rights are binding for policy making and must be considered in the process of legislation.[248] Apart from that, they also have to be taken into account in the interpretation of law.[249] While, of course, geoengineering governance instruments are not fundamental rights, a similar approach could be sought if necessary.

Finally, having taken the mentioned approaches into account, it still appears advisable to address the issue of non-state actors explicitly when incorporating geoengineering governance legislation. An example can once again be found in human rights law, more specifically in the Human Rights Act 1998 in the UK.[250] This legislation sets out that non-state actors with functions of a public nature carrying out acts that are not of a private nature have human rights obligations under the Act.[251] In the context of geoengineering, wealthy individuals would potentially be able to carry out large-scale operations that could be identified as functions of public nature rather than functions of private nature. This leads to the conclusion that, especially regarding SRM methods, the introduction of a similar rule would be advisable, as measures need to acknowledge the matter's special character and include regulations that can effectively bind public and non-state actors.

In the context of liability, various scholars also call for compensation mechanisms as a certain risk remains even with precautions in place.[252] An example of reparation procedures under international law can be found under the Rome Statute of the ICC, which is probably the most important major international instrument that addresses reparations and compensations.[253] Article 75 states that, "[t]he Court shall establish principles

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[243] *Id*. at 180; See Bodansky, *supra note 92*, 547-548.
[244] Andrew Clapham, 'Non-State Actors' in Daniel Moeckli, Sangeeta Shah & Sandesh Sivakumaran (eds), *International Human Rights Law* (4th edn, Oxford University Press 2022) 602.
[245] *Id*. at 592-593.
[246] Article 288 of the Treaty on the Functioning of the European Union.
[247] See Andrew Clapham, *supra note 244*, 595.
[248] Christoph Grabenwarter, Michael Holoubek, *Verfassungsrecht – Allgemeines Verwaltungsrecht* (4th edn Facultas Verlags- und Buchhandels AG 2019) para 421-422.
[249] *Id*. at para 422.
[250] See Andrew Clapham, *supra note 244*, 594.
[251] *Id*. at 594.
[252] See Reynolds, *supra note 90,* 185.
[253] Matthew F. Putori, 'The International Legal Right to Individual Compensation in Nepal and the Transitional Justice Context' (2011) 34(4) *Fordham International Law Journal* 1131, 1159; for a detailed analysis of the Rome Statute in the context of climate change and specifically of the crime of ecocide see Giovanni Chiarini, *Centre for Criminal Justice & Human Rights Working Paper No.15. Ecocide and International Criminal Court Procedural Issues: Additional Amendments to the 'Stop Ecocide Foundation' Proposal* (Giovanni Chiarini 2021); Rome Statute of the International Criminal Court, 17 July 1998, 2187 UNTS 90 (Rome Statute of the ICC).

relating to reparations to, or in respect of, victims, including restitution, compensation and rehabilitation."[254] Similar approaches can be found in a number of regional instruments, such as the European Convention on the Compensation of Victims of Violent Crimes or the 1998 Protocol to the African Charter which established the African Court of Human and People's Rights.[255] Apart from that, guidance can also come from case law. In *Factory at Chorzów*, the Permanent Court of International Justice stated that, "it is a principle of international law that the breach of an engagement involves an obligation to make reparation in an adequate form. Reparation therefore is the indispensable complement of a failure to apply a convention and there is no necessity for this to be stated in the convention itself."[256] While this could be a basis for reparation claims, the most desirable approach would of course be the inclusion of dedicated procedures in a geoengineering framework.

(c) Building the Foundations – Research, Flexibility, and Public Participation

Geoengineering methods may be the largest-scale human interference with natural processes of all time. Steps taken would potentially be irreversible and they would affect billions of people on the planet. Therefore, "those affected by [the] decision should have a say in its making."[257] In general, the "right of public participation in environmental decision making […] entails a right of access to information; public participation in decision making; and effective access to judicial and administrative proceedings, including remedies and redress."[258] The possibility of large-scale climate engineering makes those rights and aspects particularly important. It is essential that "the voices of the most vulnerable to climate change [and subsequentially to climate engineering] [are] heard and acted upon."[259] According to the a report of the Office of the High Commissioner for Human Rights, "public participation rights encompass the rights to be consulted at each phase of legislative drafting and policymaking, to voice criticism and to submit proposals aimed at improving the functioning and inclusivity of all governmental bodies".[260] The same report also includes several recommendations that are equally relevant for public participation in the context of geoengineering: It specifically highlights the importance of "information and educational materials in accessible formats and languages", "the development of social media platforms and associated opportunities to freely take part in online activism", "the use of new and assistive technologies to improve access to political and public life for people with disabilities", and the need for development of "specific strategies for the promotion and protection of political and public participation rights".[261] It should be stressed that individual states play a key role in the participatory process. Firstly, as international organisations do usually not have the means and necessary presence in each country, states would need to inform their citizens, carry out potential referenda, and ensure the maximisation of inclusiveness and accessibility. Secondly, it may not be possible to evaluate and consider the views of the entire planet's population individually. Therefore, national governments will need to serve as a proxy for public participation. In this regard, close compliance with the opinion of the people is crucial.

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[254] See Rome Statute of the ICC, *supra note 253*, Article 17(1).
[255] See Matthew F. Putori, *supra note 253*, 1160.
[256] *Case Concerning the Factory at Chorzów* (*Germany v Poland*) (Merits) PCIJ Rep Series A No 17, 21.
[257] See Rayner *et al*, *supra note 215*, 505-506.
[258] Jane A. Flegal *et al*, 'Solar Geoengineering: Social Science, Legal, Ethical, and Economic Frameworks' (2019) 44 *Annual Review of Environment and Resources* 413.
[259] Mary Robinson Foundation for Climate Justice, 'Ensure that Decisions on Climate Change are Participatory, Transparent and Accountable' (no date) <https://www.mrfcj.org/principles-of-climate-justice/ensure-that-decisions-on-climate-change-are-participatory-transparent-and-accountable/> accessed 24 March 2023.
[260] UNHCHR 'Report of the Office of the United Nations High Commissioner for Human Rights: Factors that impede equal political participation and steps to overcome those challenges' (30 June 2014) UN Doc A/HRC/27/29, para 21.
[261] *Id.* at paras 95, 97 and 100.

In order to base decisions on climate engineering on sufficient scientific knowledge, more research on the risks and potentials of possible methods is necessary. Calls for enhanced scientific analysis, especially regarding SRM approaches, have been published by numerous authoritative bodies, among others by the Royal Society of London and the US National Academies.[262] However, it must be acknowledged that climate engineering research of an appropriate scale may in itself be hazardous. Therefore, specific rules for research are an important aspect of governance. In order to get valid results within a shorter period of time, the disclosure of research plans and the requirement of publicising results openly are crucial.[263] This would not only support research and create synergies, but it would also allow the public to access more reliable information and data.[264]

It has of course to be noted that this includes certain risks. Information that is publicly available can always be used in harmful ways. However, in this regard "[t]he burden of proof should fall on the advocates of any restrictions."[265] While this may sound risky, the strong public interest should be highlighted again. Even if making scientific results available publicly comes with a certain risk, it may be crucial in the fight against climate change and is arguably less risky than carrying out large-scale geoengineering activities without prior research. To limit the risks caused by research, the Royal Society has suggested establishing an international scientific collaboration to "develop a code of practice for geoengineering research and provide recommendations to the international scientific community for a voluntary research governance framework."[266] Apart from that, continuous research assessment is essential. "Assessments should address both the environmental and socio-economic impacts of research, […] they should include risk reduction requirements […], [and] they could also provide a basis for establishing liability for undesirable side effects."[267]

Finally, a major challenge of geoengineering governance can be described as the "technology control dilemma", a concept first introduced by David Collinridge.[268] Essentially, the problem is that it would be desirable to regulate technology appropriately in an early development stage, but that this is almost impossible due to the unpredictability of the future development. However, as soon as technologies matures, it is often too late to introduce regulations without causing major disruptions.[269] This problem, obviously, intensively applies to geoengineering: While practical large-scale research is highly unpredictable, bears certain risks, and should therefore be regulated appropriately, the mentioned unpredictability makes it almost impossible to produce governance rules that do not impede the conduct of (well-needed) research. To avoid an undesirable stale-mate condition, governance must be responsible enough to limit the risks to a bearable degree, but it must also be flexible enough to ensure appropriate progress in geoengineering research. Potential solutions to the technology control dilemma should be based on close cooperation between research conductors and regulators and continuing assessment and adaption of the measures that are in place. Certain elements could be inspired by legal sandboxes, a concept that has successfully been introduced in a variety of fields ranging from financial regulation to data protection law and the trade with energy.[270] With climate engineering being a highly innovative and volatile field, legal answers that are inter-disciplinary and equally innovative are needed.

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[262] See Reynolds, *supra note 90*, 180.
[263] See Rayner *et al*, *supra note 215*, 506.
[264] *Id*. at 506.
[265] *Id*. at 506.
[266] See the Royal Society, *supra note 12*, 61.
[267] See Rayner *et al*, *supra note 215*, 507.
[268] Anders Hansson, Steve Rayner & Victoria Wibeck, 'Climate engineering' in Karin Bäckstrand and Eva Lövbrand (eds), *Research Handbook on Climate Governance* (Edward Elgar Publishing 2015) 412.
[269] *Id*. at 412-413.
[270] Christoph Krönke, 'Die Regulatory Sandbox – Maßanfertigung oder Multifunktionstool?' (2022) 49(1) *Österreichische Zeitschrift für Wirtschaftsrecht* 4. Legal sandboxes enable actors that are planning to carry out innovative activities that

2. A Dedicated Geoengineering Framework? – Looking for a Suitable Governance Forum

While specific governance aspects could be implemented on a regional level, a dedicated regulatory framework would mainly make sense in the shape of an international instrument.[271]

As geoengineering potentially affects a broad variety of different policy areas, a major question is, which regulatory framework(s) should "govern or guide research, development, demonstration and deployment of climate engineering."[272] An essential question is if the creation of a new international regulatory regime is necessary. According to Jesse Reynolds, this "could be beneficial but would be very difficult."[273] Some scholars suggest that creating new specific international forums may not be necessary and that appropriate geoengineering regulation and governance could also be achieved "through the application, modification and extension of existing treaties and institutions governing the atmosphere, the ocean, space and national territories."[274] Especially the London Convention, the London Protocol, and the Convention on Biological Diversity contain certain rules already.[275] However, with geoengineering including several highly different approaches, the best solution would be a dedicated regulatory instrument. It is widely agreed that the relevant rules and guidelines need to be defragmented and that the field that is most suitable for including all relevant objectives would be climate change law.[276] While almost every geoengineering approach has potential touching points with more than only one legal area, climate change law is the area that all possible methods have a certain proximity with. It can be stated that the most reasonable approach would probably be embedded in the UNFCCC.[277] The fact that the climate change framework is highly universal and inclusive makes it a suitable option for the introduction of geoengineering governance measures. Regulations of this kind would be particularly important regarding SRM techniques. For CDR methods, the most desirable approach would likely be a thought-through interplay between UNFCCC, regional and national legislation, and other international forums like the London Convention and the London Protocol.

3. Future Challenges: Human Rights Law and Climate Justice

The human rights aspect of geoengineering has, according to Jesse Reynolds, not been examined by any scholar so far.[278] Nevertheless, the question is as interesting as it is important and may become even more relevant in the future: Could individuals raise human rights-based claims, in favour of or, respectively, against the use of geoengineering methods? While the specific focus of this dissertation makes an in-depth analysis of the issue impossible, a brief look shall be taken at the potential of this approach as it may become a relevant aspect to consider in the future.

Firstly, it needs to be acknowledged that there is no explicitly mentioned human right to be free of geoengineering or to the reduction of climate change risks using geoengineering. However, there are several

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would hardly be possible under regular law. Under an authority's close supervision, the activities can be tested, and thereby knowledge can be gained. Steps taken must be protocolled closely.

[271] Ralph Bodle *et al*, 'Options and Proposals for the International Governance of Geoengineering' (2014) 14 *Climate Change* 201.

[272] See Hansson *et al*, *supra note 268*, 414.

[273] See Reynolds, *supra note 90*, 181.

[274] See Hansson *et al*, *supra note 268*, 414. See also: The Royal Society, *supra note 266*; Bodansky, *supra note supra note 92*; Gerd Winter, 'Climate engineering and international law: last resort or the end of humanity?' (2011) 20 *Climatic Change*.

[275] See London Convention, *supra note 102*; see London Protocol, *supra note 102*; see CBD, *supra note 133*.

[276] See Krüger, *supra note 216*, 463-472.

[277] See Bodle *et al*, *supra note 212*, 201.

[278] See Reynolds, *supra note 90*, 186.

rights that could serve as a basis for claims of this kind. Simon Caney, one of the most important proponents of a human rights approach to climate change, focusses on three of the most fundamental human rights that may potentially be violated by climate change: the right to life, the right to health, and the right to subsistence.[279] These rights could, contrastingly, also be impaired by the use of geoengineering. To start with, climate change can harm the right to life and the right to health as it leads to an increased frequency and severity of extreme weather events that can result in injuries and suffering or even in the death of individuals.[280] Apart from that, climate change also threatens the existence of entire communities or even states, thereby endangering the lives and the well-being of populations on a large scale.[281] The right to subsistence is threatened as climate change may lead to increased food insecurity and decreased agricultural crop production or even crop failure.[282] All these circumstances could potentially serve as a basis of a claim for the introduction of effective measures against climate change. While their effectiveness has not been fully explored, it may be assumed that the outcome of at least some geoengineering methods could be sufficiently successful in reducing the effects of climate change. However, while they would be a possible approach that could be chosen to satisfy human rights claims connected with climate change, it appears inappropriate to assume that geoengineering would be the only feasible method – at least if less risky approaches would potentially be able to solve the issue.

Contrastingly though, there are scenarios that are even more difficult to assess and that should not be dismissed too thoughtlessly: considering the cases of island states that seem to be doomed to go under water within the next few decades, a claim for the use of geoengineering could potentially have high chances to succeed. Especially fast and effective (yet risky) SRM methods may well be the only approach that could hypothetically still be able to stop the seemingly unstoppable sea level rise. It is unclear if claims aimed at the use of those methods would be successful.[283] However, there is a certain possibility that cannot be ignored, particularly in extreme cases.[284]

A different perspective can be identified in the human right to an adequate environment. This right is prominently articulated in the 1972 Stockholm Declaration.[285] Especially Principle 1 strongly links human rights and the protection of the environment.[286] Intriguingly, both arguments in favour and against the use of climate change, can arguably be found in the Declaration. First, it should be mentioned that it is sometimes suggested that a specific right to a stable climate can be derived from the right to an adequate environment.[287] Making the case for the use of geoengineering, it could then be argued that the right to a stable climate is violated by the ongoing radical climate change and that the only way of stabilising this development sufficiently could be geoengineering, especially SRM methods. Apart from that, the Stockholm

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279 Simon Caney, 'Climate change, human rights and moral thresholds' in Stephen Humphreys and Mary Robinson (eds), *Human Rights and Climate Change* (Cambridge University Press 2009) 75-83.

280 Sheila R. Foster & Paolo Galizzi, 'Human rights and climate change: building synergies for a common future' in Daniel A. Farber & Marjan Peeters (eds*), Climate Change Law Volume I* (Edward Elgar Publishing 2016) 46.

281 See Foster & Galizzi, *supra note 280*, 46; Christopher Pala, 'Kiribati's president's plans to raise islands in fight against sea-level rise,' *The Guardian* (10 August 2020) <https://www.theguardian.com/world/2020/aug/10/kiribatis-presidents-plans-to-raise-islands-in-fight-against-sea-level-rise> accessed 24 March 2023; Stefica Nicol Bikes, 'Tuvalu looking at legal ways to be a state if it is submerged,' *Reuters* (9 November 2021) <https://www.reuters.com/business/cop/tuvalu-looking-legal-ways-be-state-if-it-is-submerged-2021-11-09/> accessed 24 March 2023.

282 See Foster & Galizzi, *supra note 280*, 46.

283 See also B. I. (b) Solar Radiation Management Methods (SRM).

284 It should not be forgotten that, while in the scenarios mentioned only the affected island states population could potentially raise those claims, the effect of SRM methods would usually not be limited to a specific region but would probably have an impact on a large area, if not the whole planet.

285 See Stockholm Declaration, *supra note 88*.

286 See Foster & Galizzi, *supra note 280*, 49.

287 *Id.* at 49.

Declaration itself contains various wordings that could be interpreted in favour of climate engineering. Principle 1 stresses the responsibility to protect and improve the environment for present and future generations."[288] Especially the aspect of "improve" could be interpreted to legitimise or even demand geoengineering, as it could well be a way of improving the environment by preventing extreme weather conditions and other climate hazards. Even more so, the proclamation that precedes the principles of the Declaration contains various wordings that could lead to the conclusion that the use of geoengineering may be desirable, if not an obligation under the Stockholm Declaration.[289] For instance, it calls the human being the "moulder of his environment", mentions that, "through the rapid acceleration of science and technology, man has acquired the power to transform his environment in countless ways and on an unprecedented scale" and claims that, "[b]oth aspects of man's environment, the natural and the man-made, are essential to his well-being and to the enjoyment of basic human rights the right to life itself."[290] It is further claimed that "[m]an has constantly to sum up experience and go on discovering, inventing, creating and advancing" and that "[i]n our time, man's capability to transform his surroundings, if used wisely, can bring to all peoples the benefits of development and the opportunity to enhance the quality of life."[291]

Contrastingly, various human rights-based arguments can also be found against climate engineering. For instance, the formerly mentioned proclamation of the Stockholm Declaration states that, "wrongly or heedlessly applied, the [power to transform the environment] can do incalculable harm to human beings and the human environment" and mentions "major and undesirable disturbances to the ecological balance of the biosphere."[292] Apart from that a "point has been reached in history when we must shape our actions throughout the world with a more prudent care for their environmental consequences."[293] More generally, considering the possible human right to a stable climate, it cannot be stressed enough that there is no sufficient proof that geoengineering would actually stabilise the climate. Much more so, some methods could even lead to unpredictable reactions that may destabilise the climate even further. Concludingly, the human rights perspective does not provide a fully clear answer to the question of geoengineering yet. As arguments can be found against and in favour of artificial climate alteration, it may be a matter that needs to be clarified through international agreements or case law in the future.

In its final paragraph, the Proclamation of the Stockholm Declaration highlights the importance of local and national governments for large-scale environmental policy and action within their respective jurisdictions and stresses the relevance of extensive international cooperation in the common interest.[294] This basic principle of common effort and cooperation is crucial – both in the struggle against climate change and in the search for appropriate geoengineering governance.[295]

Finally, an aspect that is becoming increasingly important is the climate justice perspective. For instance, geoengineering techniques could potentially change weather patterns, effectively moving phenomena like the Indian monsoon to a different location.[296] This would not only disrupt ecosystems, but it would also have grievous impacts on food supply. The potential of millions of people starving to death after a state, a group of states, or even an individual carries out geoengineering activities in a completely different part of the world is highly dangerous. Especially the scenario of developed countries improving their situation while

[288] See Stockholm Declaration, *supra note 88*, Principle 1.
[289] Having stated this, it needs to be stressed that the Stockholm Declaration is a non-binding document, and that the proclamation is even less binding, yet relevant in the interpretation of the document.
[290] See Stockholm Declaration, *supra note 88*, Proclamation 1.
[291] *Id*. at Proclamation 3.
[292] *Id*. at Proclamation 3.
[293] *Id.* at Proclamation 6.
[294] *Id.* at final paragraph.
[295] See also (b) Solving Problems – Subsidiarity and Liability.
[296] See Hamilton, *supra note 5*, 54-55; see also above *Solar Radiation Management.*

consequentially accepting disastrous situations in other countries that are not able to carry out geoengineering activities themselves could be a major issue in the future. These serious questions of climate justice cannot be fully examined in this dissertation. However, they show strikingly how dangerous especially unregulated climate engineering could become and they amplify the call for dedicated governance measures.

E. CONCLUSION

The question if climate engineering should (or needs to) be implemented cannot be answered here. As mentioned above, a certain amount of geoengineering activities may be inevitable already. However, to get to a clear solution, further scientific research is necessary. What is clear though is that finding answers to the questions of climate engineering should be a priority for governments, researchers, and organisations everywhere in the world. If clear decisions are not taken in an institutionalised context now, they may timely be taken by actors that are not subjects of international law – and possibly in a way that may have hazardous consequences for present and future generations.

Under *lex lata*, various areas of international law are relevant for the assessment of climate engineering activities and a certain fragmentation can be identified. While some frameworks – especially the law of the sea and the Convention on Biological Diversity – tackle the issue explicitly, a lack of guidance is evident under many treaties and instruments. Most strikingly, climate change law provides only limited implications, even though the UNFCCC is often argued to be the most suitable context for geoengineering governance. As even general principles of international law are unable to solve some of the most pressing issues, one of the central arguments of this dissertation is that the introduction of global, universal, and transparent governance should be sought, most desirably under the UNFCCC.

An instrument of this kind would need to consider various aspects. Most crucially, procedures for public participation, solid guidance for dealing with non-state actors, effective yet flexible rules for research, and a firm foundation for cooperation and joint decision-making would be necessary. The general approach should be balanced between the necessity of further research, the protection of the planet and its ecosystems, and indisputable limits for high-risk technologies. Especially SRM methods are potentially dangerous and should be prohibited strictly. However, as climate change is highly dynamic and future developments are difficult to predict, further research should be possible under strict supervision – especially with regard to potential emergency scenarios. On the other hand, CDR methods are argued to be less risky, yet more expensive and not as fast. Nevertheless, some approaches could potentially be implemented to support ongoing emission reductions. It should be stressed again though that prior to any implementation steps, precise, binding, and science-based governance rules must be in place. Extensive research and risk minimisation is crucial, and precaution needs to be a top priority.

Additionally, it cannot be stressed enough that, even if certain implementation steps would be taken, geoengineering can never be seen as the primary solution to climate change. As it can only be used as a supportive measure to the minimisation of greenhouse gas emissions, the focus of research and innovation should clearly be put on emission minimisation solutions. Even well-researched, carefully implemented climate engineering under close supervision and guidance can at most serve as a potential addition. To reduce the release of greenhouse gases effectively, approaches need to be multi-disciplinary, fast, and sometimes even radical. Especially nature-based solutions could contribute valuably to successful climate mitigation. Ultimately, only a combination of multiple different approaches and techniques will be able to lead to success. All stops will need to be pulled out. The law plays the essential role of directing, controlling, and governing the whole process. Especially the climate justice perspective strikingly stresses the urgent need for action.

Finally, the most dangerous aspect of climate engineering is also the one all potential methods and approaches have in common: They convey a false sense of security and distract attention. Researching climate engineering and considering the careful supplementary implementation of some measures can be beneficial. However, our focus must never shift from the exhausting and painful reduction of emissions towards seemingly simple and fast geoengineering solutions. If it ever does, if we ever end up abandoning the unpleasant path to follow the ignis fatuus, the struggle against climate change may be lost inevitably.

"The ultimate test of a moral society is the kind of world that it leaves to its children."[297]

[297] Source unknown, commonly attributed to Dietrich Bonhoeffer; see for example <https://www.brainyquote.com/quotes/dietrich_bonhoeffer_385907> accessed 24 March 2023. Dietrich Bonhoeffer (1906-1945) was a German theologian who was murdered for resisting the Nazi regime <https://www.britannica.com/biography/Dietrich-Bonhoeffer> accessed 24 March 2023.