Chapter 9
Geoengineering: Methods, Associated Risks and International Liability

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9.1 Introductory Remarks

1 Climate change arguably constitutes one of the greatest risks to the long-term health of the world's environment. In 2015, the Intergovernmental Panel on Climate Change (IPCC) highlighted that the Earth's climate system has consistently been warming since the 1950s and that a "large fraction of anthropogenic climate change resulting from CO_2 emissions is irreversible on a multi-century to millennial time scale, except in the case of a large net removal of CO_2 from the atmosphere over a sustained period".[1] Initial responses to climate change revolved around States attempting to reduce, rather than remove, greenhouse gas emissions.[2] However, as the global economy expands, greenhouse gas emissions have continued to rise and cooperative arrangements aimed at reducing emissions have had limited, if any, impact. If recent predictions are to be believed, the remaining "carbon budget" needed to prevent average global temperatures from increasing by more than 1.5 °C may be exhausted by 2030.[3] Climate Analytics estimates that the current Nationally Determined Contributions (NDCs) made by States under the Paris Agreement[4] indicate that average global temperatures will rise by 2.8 °C by 2100—almost double the stipulated efforts to limit the temperature increase to 1.5 °C above pre-industrial levels mentioned in Article 2(1)(a) of the Paris Agreement.[5] The recent IPCC Special Report on 1.5 °C Global Warming concludes that without "increased and urgent mitigation ambition in the coming years, leading to a sharp decline in greenhouse gas emissions by 2030, global warming will [cause] irreversible loss of the most fragile ecosystems and crisis after crisis for the most vulnerable people and societies".[6]

2 As the effects of climate change become more apparent and the need for action becomes more urgent, it is unsurprising that scientists, governments and policymakers have begun considering climate change strategies that go beyond the reduction of greenhouse gases. This is especially true in the context of contemporary environmental law where commitments to protect the environment are sometimes held to imply that States should consider innovative actions.[7] In this regard, geoengineering (at times also referred to as 'climate engineering', or 'climate-altering technologies')[8] is emerging as a potential response to tackling climate change.

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[1] Alexander et al. (2013), p. 28.

[2] Schipper (2006).

[3] Rogelj et al. (2016), p. 635. See also Brent et al., p. 2.

[4] Paris Agreement, 12 December 2015, C.N.92.2016. Treaties-XXVII.7.d (entered into force 4.11.2016) (hereinafter Paris Agreement).

[5] Climate Analytics (undated).

[6] Taalas and Msuya (2018), p. vi.

[7] Reynolds (2014), p. 430; Corry (2017), p. 300.

[8] The terminology used is not coherent. The IPCC Special Report on the Impacts of Global Warming of 1.5 °C refrains from using the term 'geoengineering' (see Masson-Delmotte et al.

The term 'geoengineering' is somewhat difficult to define since it encompasses a wide range of dissimilar techniques with varying methodologies, costs and risk levels.[9] However, it is generally accepted that geoengineering can be understood as the deliberate and large-scale manipulation of the Earth's climate to counteract anthropogenic climate change.[10] There are several methods of geoengineering but, for the present Chapter, individual methods can be classified into one of two broad categories: (1) solar radiation management (SRM) and (2) carbon dioxide removal (CDR). **3**

Before turning to an examination of the differences, risks and methods associated with the activities that fall within these categories, it is important to point out that there exists an inherent tension in the development/deployment of current geoengineering methods and the potential risks that such development/deployment may entail. On the one hand, various geoengineering methods seem to promise considerable benefits, including contributing to the overall mitigation of anthropogenic climate change.[11] On the other hand, the potential benefits to the environment and society in general may be offset by the potential harm that one and the same geoengineering method poses.[12] Risks associated with geoengineering include environmental disruptions such as droughts; permanent damage to the ozone layer; an increase in acid rain; negative effects on ocean ecosystems; as well as political and social risks associated with human security. Furthermore, curbing the effects of climate change could lead to 'moral hazard' and deter States, as well as private stakeholders, from carrying out more costly and sometimes internationally mandated climate change mitigation measures.[13] With a wide array of political, environmental, social and economic risks at play, questions arise as to the compatibility of geoengineering operations with international law. This is especially true given that there are currently no binding international regulations in force that specifically focus on geoengineering as current regulation primarily relies on existing multilateral agreements established for other purposes.[14] **4**

2019, Annex I, p. 550). Similarly, the Carnegie Climate Governance Initiative (2019) is attempting to limit use of the term 'geoengineering' to specific situations (see https://www.c2g2.net/whats-in-a-name-why-we-became-c2g/ and explanation of core terms: https://www.c2g2.net/terminology-guide/; accessed 1 Apr 2022). As far as ocean-based interventions are concerned, the terminology used in multilateral fora has recently shifted to 'ocean-based negative emission technologies' and 'ocean interventions for climate change'. See IMO Doc. LC/SG 44/3/Add.1, 29 March 2021, Marine Geoengineering: Advice from GESAMP Working Group 41 to the London Protocol Parties to Assist them in Identifying Marine Geoengineering Techniques that it Might be Prudent to Consider for Listing in the New Annex 4 of the Protocol.

[9] Bodle et al. (2014).

[10] Royal Society (2009), p. 1.

[11] Bodansky (2013), p. 540.

[12] Scott (2013), p. 313; Reynolds (2014), p. 427.

[13] ¶ 49 *et seq* for an analysis of the risks associated with current geoengineering methods. See also Horton et al. (2013).

[14] Talberg et al. (2017), p. 229.

5 Additionally, and unlike the ambiguous distribution of responsibility associated with CO_2 emissions, the deliberate and large-scale development or deployment of geoengineering methods may be attributable to identifiable actors.[15] The difficulties inherent in measuring, as well as attributing where possible, the effects of deploying a particular geoengineering method may lead to an increase in potential conflicts surrounding international liability and compensation. It is largely accepted, therefore, that the deployment of any geoengineering technology needs to be done against the backdrop of an existing and effective governance regime that includes international liability.

6 This Chapter is divided into five Subchapters. Following the introduction in Sect. 9.1, Sect. 9.2 briefly examines the definition of geoengineering before turning to a survey of the categories of geoengineering together with each category's associated methods in Sect. 9.3. This latter Subchapter provides an analysis of the major environmental and other risks associated with geoengineering. Section 9.4 analyses the international legal rules and principles that are currently relevant or have the potential to be relevant in the context of large-scale geoengineering activities. This Subchapter provides an overview concerning the key regimes that may be called on to govern geoengineering proposals, including the London Convention/Protocol,[16] the 1982 United Nations Convention on the Law of the Sea (UNCLOS), the outer space treaty system as well as customary international law rules and principles associated with the prevention of harm from activities that may have significant and adverse impacts on the environment. Using those liability regimes identified and examined earlier in the study, Sect. 9.5 highlights the options available for international responsibility and liability for damage caused by geoengineering activities. This Subchapter also includes a discussion of the challenges in attributing responsibility and liability for geoengineering activities and concludes with an examination of what a potential geoengineering liability regime may consist of.

9.2 Definition of Geoengineering and Terminology

7 For the present study, it is important to note from the outset that the terms 'geoengineering' and 'climate engineering' are used interchangeably.[17] Where specific differences between these terms are intended, such intention is expressly stated. Additionally, this Chapter adopts the accepted view that geoengineering does not

[15] Lawrence et al. (2018), p. 5.

[16] Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 29 December 1972, 1046 UNTS 120 (entered into force 30 August 1975) (London Convention); Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 14 November 1996, 36 ILM 7 (Protocol to the London Convention).

[17] See Rickels et al. (2011, p. 7) for a potential distinction between the term 'geoengineering' and 'climate engineering'. However, this distinction is not utilised within this study, primarily since such a distinction is based on intention rather than a difference in content or meaning. In the present

include 'traditional' mitigation or adaptation strategies, including industrial carbon capture, nor does it include strategies that do not involve deliberate intervention in the climate system, including conventional afforestation and avoided deforestation.

There are currently several accepted definitions for the term 'geoengineering'.[18] **8**
The Royal Society defines geoengineering as the "deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change".[19] The parties to the Convention on Biological Diversity (CBD) view the term as referring to "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)".[20] For the present Chapter, these definitions are used to conclude that for any proposed activities to be classed as geoengineering they must be:

- Deliberate;
- Aimed at addressing anthropogenic climate change;
- Of such a large-scale that the implementation of any particular geoengineering method is designed to significantly counteract the effects of anthropogenic climate change;[21] and
- The activity falls within one of two broad categories: solar radiation management or carbon dioxide removal.

It is relevant to mention that the above definitions of geoengineering are not **9**
without problems. Most notably, some argue that the benefits, associated risks and potential cost portfolios of individual methods are too varied to be referred to under one umbrella term.[22] Such arguments may be countered by the fact that a collective term provides both a degree of commonality and advantages in the development of governance regimes. However, such terminology may also create a false impression as no geoengineering methods have thus far been undertaken beyond small-scale field experiments.[23] Needless to say, what qualifies as geoengineering is currently still being discussed, and the term should be viewed as referring to "a contested

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study, therefore, the only concern for the definition of geoengineering is that the relevant activities are undertaken deliberately.

[18] GESAMP (2019), pp. 16–17.

[19] Royal Society (2009), p. 1; see also Secretariat of the Convention on Biological Diversity (2012), p. 23 for a similar definition.

[20] The definition is contained in a footnote to Decision X/33 on Biological Diversity and Climate Change adopted by the 10th Conference of the Parties (COP) to the CBD, https://www.cbd.int/decision/cop/?id=12299, accessed 1 Apr 2022. Even if it may sometimes be difficult to distinguish between nature conservation and climate intervention on the basis of intent, conventional measures of nature conservation cannot be held to potentially negatively affect biodiversity in terms of the CBD definition.

[21] Secretariat of the Convention on Biological Diversity (2012), p. 23.

[22] Heyward (2015).

[23] Boettcher and Schäfer (2017), p. 267.

concept that unites a set of heterogeneous proposals for how a targeted intervention into the climate system might be achieved”.[24]

9.3 Categories and Risks of Geoengineering

10 In line with the definition of geoengineering outlined above, this Chapter distinguishes between different methods of geoengineering based on their inclusion in one of two broad categories. Which method falls into which category generally depends on whether the method aims to “treat the ‘symptoms’ of climate change by altering the Earth’s radiation budget without reducing greenhouse gas concentrations, or whether [the method] aims to treat the ‘cause’ of climate change by reducing the greenhouse gas concentrations that have changed the Earth’s radiation budget”.[25] It is important to highlight from the outset that the present Subchapter does not offer an analysis of every available method of geoengineering.[26] Rather, this Subchapter offers a discussion of a select few methods which have been selected for their potential value in shaping a future geoengineering liability regime (see Sect. 9.6). The following discussion highlights, first, the purpose of each category and, second, the methods selected and associated with each category. It is also important to keep in mind that the present Chapter only briefly highlights the categories and associated methods and does not offer an in-depth study of the scientific aspects of each method. The relatively descriptive analysis offered here is done to set the foundation for (1) a legal examination into the potential gaps surrounding geoengineering governance, and (2) allow for a discussion of important issues to consider in the context of international liability for geoengineering activities.

9.3.1 Solar Radiation Management

11 The first category of geoengineering considered here is referred to as solar radiation management. The ultimate aim of SRM is to limit or stabilise warming caused by the increased levels of greenhouse gases in the atmosphere by reducing the amount of solar radiation the Earth absorbs. [27] SRM methods do this by increasing the

[24] Boettcher and Schäfer (2017), p. 267.

[25] Rickels et al. (2011), p. 37.

[26] For a detailed analysis of the available CDR and SRM methods, see generally Royal Society (2009); Rickels et al. (2011); Secretariat of the Convention on Biological Diversity (2012). For a detailed analysis of various SRM and CDR methods associated with marine geoengineering specifically, see GESAMP (2019).

[27] Royal Society (2009), p. 23.

reflectivity of the Earth (i.e. planetary albedo) to reduce the amount of sunlight that reaches the Earth's surface and that, in turn, would decrease average global temperatures.[28] There are predictions that SRM methods, especially stratospheric aerosol injection (SAI), would be relatively inexpensive to deploy and are designed to have an immediate impact on global temperatures. This is in contrast to CDR methods (¶ 32 *et seq*), which are predicted to be expensive and involve a substantial delay between their implementation and desired global climate impact.[29] The relative speed of deployment and predicted effectiveness of SRM methods may be an important consideration should anthropogenic climate change become immediately dangerous to those communities and species most vulnerable to increasing temperatures.[30] However, it requires particular mention that despite expectations that SRM methods will rapidly counterbalance the effects of increasing greenhouse gases, such methods do not directly address the root causes of anthropogenic climate change (i.e. increases in greenhouse gases such as CO_2).[31]

Methods common to SRM can be deployed in three spatial zones, namely, space, including mirrors and other solar reflectors; the atmosphere, including SAI, marine cloud brightening (MCB)[32] and cirrus cloud thinning (CCT); and the Earth's surface, including sea ice restoration and desert reflectors.[33] The following Subchapter limits itself to a discussion of five SRM methods. The first three methods examined in this Chapter (SAI, MCB and CCT) are currently the most discussed, with field testing already taking place in some cases, and are, therefore, important for a discussion regarding the international governance of geoengineering. The fourth method, the restoration of sea ice, is a relatively new technique and its effectiveness and environmental impacts are largely unknown. Furthermore, employing this method is also complicated by the ecologically and politically sensitive areas in which it would take effect (such as in the Arctic). However, these particularities involving sea ice restoration offer an opportunity to assess how new approaches (broadly falling under the umbrella category of SRM) can be regulated. The fifth and last method discussed in this Subchapter, space-based solar reflectors, has several implementation challenges but is discussed here for the purposes of international liability, especially taking into account the liability regime established by the Space Liability Convention discussed in Chap. 11.[34] Therefore, this study incorporates an **12**

[28] Hester (2018), p. 225; Royal Society (2009), p. 23; see also Secretariat of the Convention on Biological Diversity (2012), p. 26.

[29] Lawrence et al. (2018), p. 9.

[30] Talberg et al. (2017), p. 231; ¶ 56 *et seq* concerning human rights risks associated with geoengineering.

[31] Secretariat of the Convention on Biological Diversity (2012), p. 26.

[32] MCB is a sub-method of marine sky brightening (MSB). Since MCB is the most developed and researched form of MSB, focus is placed on MCB. However, the principles and risks associated with MCB are by and large applicable to all MSB methods in general.

[33] Lawrence et al. (2018), p. 9.

[34] Convention on International Liability for Damage Caused by Space Objects, 29 March 1972, 961 UNTS 187 (Space Liability Convention).

examination of all three of the above-cited spatial zones where SRM methods could be deployed.

13 Before examining these five methods, two points must be highlighted for this Subchapter. First, the specific risks associated with SRM in general are discussed below (¶ 49 *et seq*) while those risks associated with each of the considered methods are discussed here. This means that the risks associated with SRM in general are also applicable to all the specific methods discussed in this Subchapter. Second, it must be borne in mind that the specifics of deployment and the overall impacts of each method will depend on factors such as geographic location and whether the method is applied at the Earth's surface, in the atmosphere or in space.[35]

Stratospheric Aerosol Injection

14 Currently classified by some as one of the most promising geoengineering methods for cooling the climate, SAI involves the introduction of aerosols into the stratosphere to increase the reflection of sunlight.[36] The introduction of such aerosols has the potential to mimic the cooling effects that have been observed after large volcanic eruptions or—at lower atmospheric altitudes—in cities with air pollution.[37] Given the research surrounding volcanic eruptions, the focus on SAI has thus far been on the use of sulphate aerosols; however, this does not preclude that other types of aerosol particles may be preferred in future.[38] Recent models suggest that the sensible use of SAI has the potential to reduce temperature and precipitation anomalies at both regional as well as sub-regional levels.[39] The features of SAI were recently highlighted in the IPCC Special Report on 1.5 °C Global Warming where it was concluded that "SAI is the most-researched SRM method, with *high agreement* that it could limit warming to below 1.5 °C".[40]

15 Despite the above-mention advantages, any study on international liability requires an examination of the potential risks and side effects of current SAI technology. The risks and side effects of SAI identified in the following are in addition (in whole or in part) to the general risks associated with SRM discussed below (¶ 49 *et seq*). The first risk associated with SAI is related to the fact that the injected aerosols have the potential to damage the ozone layer. Ozone depletion has profound consequences that range from higher rates of illness in humans, such as skin cancer and cataracts, to dramatic climatic changes and crop failures.[41]

[35] Royal Society (2009), p. 23.

[36] Schäfer et al. (2015), p. 41; see also Reichwein et al. (2015), p. 145.

[37] Crutzen (2006), p. 211; Royal Society (2009), p. 29; Brent (2018), p. 161. See also Cardwell (2022).

[38] Royal Society (2009), p. 29. This is particularly important to keep in mind since some of the negative impacts caused by sulphate usage may be mitigated or even avoided if aerosols other than sulphates were to be used in SAI (Secretariat of the Convention on Biological Diversity 2012, p. 48).

[39] Irvine et al. (2019).

[40] de Connick et al. (2018), p. 350.

[41] Robock et al. (2008), p. 1; Saxler et al. (2015), p. 115; see also Burns (2010), p. 291.

Continued depletion of the ozone layer also endangers marine ecosystems, biochemical cycles and has resulted in estimates that efforts to close the ozone hole above Antarctica could be delayed by approximately 30 to 70 years.[42] In addition to the potential dangers to the ozone layer, SAI could also alter precipitation patterns and water cycles—potentially exacerbating water scarcity in certain areas and worsening El Niño events.[43] Certain models predict that SAI may negatively affect the monsoon cycle, resulting in droughts and crop failure with a consequent increased risk of famine.[44] Should such side effects materialise, SAI may intensify the effects of climate change itself. Lastly, and despite ongoing research into SAI, there still exists considerable scientific uncertainty regarding its implementation. In the absence of any past observations that could serve as benchmarks, doubt remains as to whether it is possible to reliably estimate probabilities for the occurrence of a certain type of damage stemming from SAI.[45]

Additional difficulties surrounding the implementation of SAI are related to the mechanisms through which aerosols could be injected. Current mechanisms for the injection of potential aerosols include high-flying aircraft, stratospheric balloons, artillery shells and rockets. High-flying aircraft and stratospheric balloons are currently believed to be the most effective and economically feasible. However, both of these proposed mechanisms are currently underdeveloped and identifiable issues include the need for dedicated fleets of high-flying aircraft since the altitude ceiling of commercial aircraft is too low. Regarding tethered stratospheric balloons, issues here involve the safety of transporting several megatons of aerosol particles through hoses that may stretch several kilometres.[46] **16**

Often classified as the most researched method of SRM, the risks associated with SAI highlight the critical importance of developing a robust and comprehensive liability regime. **17**

Marine Cloud Brightening

MCB is an SRM method that aims to disperse aerosols (most commonly sea salt particles) into low-level clouds which form over the ocean.[47] Sea salt particles have been identified as a major source of cloud condensation nuclei, which enhance “cloud droplet number concentrations” and therefore reduce cloud droplet size. This ultimately results in a cloud having a higher number of smaller droplets (as opposed to fewer larger droplets) and, given that more smaller droplets have a larger total surface area than fewer large droplets, this increases cloud albedo.[48] MCB offers a similar advantage to other SRM methods in that it promises increased **18**

[42] Tilmes et al. (2008), p. 1204; see also Heckendorn et al. (2009), p. 1.

[43] Saxler et al. (2015), p. 115; see also Schäfer et al. (2015), p. 44.

[44] Robock (2008), p. 15; see also Saxler et al. (2015), p. 115.

[45] Saxler et al. (2015), pp. 116–117.

[46] Lawrence et al. (2018), p. 10.

[47] Schäfer et al. (2015), pp. 44–45.

[48] Brent et al. (2019), pp. 7–8.

reflection of solar radiation with a potential secondary benefit that it may also prolong the lifespan of a cloud, further enhancing its cooling capacity.[49]

19 MCB has been described as a "significantly less risky option" than SAI, however, MCB's primary risks are still centred around scientific uncertainty regarding its deployment and overall effectiveness.[50] Brief mention should be made of the fact that in 2020, a research team led by the Sydney Institute of Marine Science and Southern Cross University conducted the first outdoor MCB field test above Australia's Great Barrier Reef. The aim of the field test was to evaluate "a delivery mechanism comprised of 100 high-pressure nozzles that can spray nano-sized sea-salt particles into the air", at a time when the Great Barrier Reef was undergoing its third mass coral bleaching event in five years.[51] This MCB field test is part of a long-term programme facilitated by the Australian Reef Restoration and Adaptation Program (RRAP) "to develop, test and risk-assess novel interventions to help keep the [Great Barrier] Reef resilient and sustain critical functions and values".[52]

20 Despite limited local testing, the potential effectiveness of MCB has only been assessed with global-scale models, which have poor spatial resolution and exclude any assessment on the scale of individual clouds.[53] Moreover, clouds are considered among the most complex and least-understood components of the climate system and the effect that large-scale MCB may have on global precipitation patterns is not fully understood.[54] In this regard, enhanced precipitation over low-latitude land areas may increase agricultural productivity in some areas while increasing the risk of floods in others.[55] Certain models predict that those areas where MCB deployment could result in decreased precipitation include South America (as an identified key target area), which could have detrimental impacts on the Amazon rainforest.[56] Additional risks posed by MCB to the environment include the fact that reduced ocean temperatures and available sunlight "could potentially alter the carbon uptake of the oceans directly by changing seawater chemistry and indirectly by changing phytoplankton production"—possibly impacting other biogeochemical cycles and ocean ecology, including potentially drastic changes to fisheries and other

[49] Brent et al. (2019), p. 8; see also Rickels et al. (2011, p. 42) highlighting that this secondary benefit has recently been challenged.

[50] Scott (2013), p. 328.

[51] Carnierge Climate Governance Initiative (2020).

[52] Website of the Reef Restoration and Adaption Program (RRAP): https://www.gbrrestoration.org/home, accessed 1 Apr 2022. The RRAP Concept Feasibility Study identified MCB as one of 43 "interventions" requiring further exploration (see Bay et al. 2019). The decision to select MCB and the other 42 "interventions" was done on the basis of their functional objective, delivery method and possible deployment scale. That said, the role that international governance (particularly international responsibility and liability for environmental damage) played in selecting the interventions appears, at first glance, minimal.

[53] Brent et al. (2019), p. 8.

[54] Schäfer et al. (2015), p. 45.

[55] Schäfer et al. (2015), p. 46.

[56] Bala et al. (2010), p. 916.

aspects of marine food webs.[57] Lastly, while the primary purpose of MCB is to increase cloud albedo, under certain circumstances the method has been shown to reduce rather than increase albedo.[58]

The above-identified risks offer challenges specific to the deployment of MCB itself. However, the underlying reason for the above risks are rooted in issues associated with effectiveness and uncertainty and are, therefore, not far removed from those risks that SAI methods face.[59] For this reason, the potentially applicable international laws surrounding the governance of SAI and MCB would be largely indistinguishable. 21

Cirrus Cloud Thinning

The third SRM method discussed in this Subchapter is CCT. Perhaps less so than SAI but comparable to MCB, CCT appears to be a technologically feasible and relatively inexpensive geoengineering method. In order to understand the purposes of CCT, it is important to briefly note that clouds generally reflect some incoming shortwave radiation whilst trapping a certain amount of outgoing longwave radiation.[60] This has resulted in the understanding that the location and high altitude of cirrus clouds result in such clouds having a warming effect—meaning that their dispersal, by scattering ice nuclei, could reduce global warming.[61] The presence of such ice nuclei in the atmosphere "would result in fewer, but larger ice particles being produced during cirrus cloud formation, thus causing them to sink more rapidly".[62] 22

The primary advantage associated with CCT is that the material and costs involved in its deployment are relatively minimal. The ice nuclei would only be needed in low quantities and, unlike SAI methods, could be deployed using available commercial aircraft.[63] Recent studies related to CCT have, as with other methods, highlighted the scientific uncertainties and unpredictable consequences of CCT. Some of these studies have concluded that despite significant increases in scientific understanding of CCT in recent years, this method of geoengineering does "not achieve a significant climatic effect",[64] whereas other studies point to evidence that CCT could lower average global temperatures by up to 1.4 °C.[65] Further complicating the picture of its usefulness, certain other studies have found that CCT, not unlike 23

[57] Partanen et al. (2016), p. 7607; Brent et al. (2019), p. 8.

[58] Robock et al. (2013); see also Ahlm et al. (2017), p. 13071; and Brent et al. (2019), p. 8.

[59] Lawrence et al. (2018), p. 10.

[60] Factors that affect whether short- or longwave radiation are blocked by clouds include the latitude of the clouds, their altitude and particle size. However, the deciding factor in determining whether a cloud locks short- or longwave radiation seems to be a cloud's latitude (Rickels et al. 2011, p. 42).

[61] Reynolds (2019a).

[62] Rickels et al. (2011), p. 42.

[63] Rickels et al. (2011), p. 42.

[64] Lohmann and Gasparini (2016).

[65] Storelvmo et al. (2014), p. 4.

MCB, carries with it the risk to increase, rather than decrease, average global temperatures. This risk is attributable to the over-seeding of ice nuclei that would result in optically thicker cirrus clouds which, in turn, provide a net warming effect instead of cooling.[66]

24 The constraints associated with large gaps in currently available scientific knowledge, including environmental side effects and overall effectiveness, means that an in-depth analysis of this method is unnecessary for this Chapter. Needless to say, it is predicted that any development or deployment of CCT methods will need to be bound by the same international governance regime applicable to SAI and MCB.

Restoration of Sea Ice

25 As far back as 1965, it was suggested that threats associated with climate change could be addressed by "spreading very small reflecting particles over large oceanic areas" to increase the ocean's reflectivity.[67] In recent years, a few studies have concluded that microbubbles or foam created at the surface of the ocean has the potential to increase ocean albedo.[68] Findings in these studies suggest that the creation of such foam and microbubbles at the ocean's surface has the potential to substantially reduce average global temperatures, with particularly positive impacts in the ice-covered polar regions.[69] In this regard, the Ice911 Research project, which focuses on the Arctic, requires brief mention.

26 A new proposal by this research team suggests placing certain types of sheet or granular material (such as a hollow glass microsphere solution) on Arctic ocean surfaces.[70] It is envisaged that the use of such material or solution (described as having a low subsidiary environmental impact) would increase ice reflectivity in the region and consequently reduce currently projected temperature increases.[71] In February 2020, the Ice911 project, recently renamed the Arctic Ice project, began field-testing in Winnipeg, Canada.[72] It has been predicted that the use of this hollow glass microsphere solution has the potential to increase Arctic ice volumes by up to one per cent per year, as well as substantially reduce regional temperatures.[73] Supporters of this project have labelled this method as "soft-geoengineering" as it

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66 Lohmann and Gasparini (2017); Kristijánsson et al. (2015), p. 10,809.

67 President's Science Advisory Committee (1965).

68 In this regard see the following studies: Evans et al. (2010), p. 155; Crook et al. (2016), p. 1549; and Seitz (2011), p. 365.

69 Brent et al. (2019), p. 9; see also Desch et al. (2016), p. 107, where another method of restoring ice in the Arctic is discussed. This latter research study indicates the possibility of "enhancing Arctic sea ice production by using wind power during the Arctic winter to pump water to the surface, where it will freeze more rapidly". This study concludes that "where appropriate devices are employed, it is possible to increase ice thickness above natural levels, by about 1 m over the course of the winter".

70 Field et al. (2018), p. 884.

71 Field et al. (2018), p. 882.

72 Arctic Ice Project (2021).

73 Field et al. (2018), p. 896.

has less associated risks and is easily withdrawn from use compared to other geoengineering options.[74]

However, as with all methods of geoengineering currently under discussion, the long-term effects of increasing ocean albedo are not well known. Potential environmental impacts associated with such methods are numerous—including the potential to exacerbate ocean acidification, negatively influence ocean species as a result of changing temperature effects and reduced sunlight as well as potentially changing global and or regional precipitation patterns.[75] Considering the use of such (or similar) methods in the highly sensitive polar regions carries with it increased environmental risks,[76] where the disruption or a slowing of ice melting patterns may impact fragile ecosystems and the habitat and migration patterns of Arctic or Antarctic species found nowhere else on Earth. Apart from these environmental concerns, the proposal of the Arctic Ice Project discussed above may also pose human rights issues associated with indigenous peoples. Some commentators have expressed concern that the indigenous peoples of the Arctic have not consented to or do not fully appreciate the extent that geoengineering research and deployment in the Arctic may have on local ecology, which ecology may already be under pressure from existing extraction projects related to oil and gas wells and other forms of mining. [77] **27**

The restoration of sea ice by increasing ocean or ice albedo (as in the Arctic Ice project) has received considerably less attention than other methods of geoengineering. In the absence of detailed scientific information, the uncertainties regarding this method of SRM make any evaluation of potential cost and effectiveness that much more complex. **28**

Space-Based Solar Reflectors

The last method of SRM detailed in this Chapter involves the installation of reflective mirrors between the Earth and the Sun to reduce incoming solar radiation.[78] Installation options include placing mirrors between the Earth and the Sun or in orbit around the Earth. Additional options include deploying either a 'cloud' of reflective spacecraft or an artificial equatorial ring of passive particles.[79] Not unlike other SRM techniques, the use of space-based solar reflectors offers to compensate for much of the warming caused by anthropogenic CO_2 emissions in a relatively short amount of time.[80] **29**

[74] Geoengineering Monitor (2018).

[75] Robock (2011), p. 383; Brent et al. (2019), p. 9.

[76] The fragility of the Arctic is exemplified by findings that it is warming at twice the rate of the global average (see Clark and Lee 2019, p. 8490).

[77] Geoengineering Monitor (2019).

[78] Lunt et al. (2008), p. 1.

[79] Kosugi (2010), p. 242; Pearson et al. (2006), p. 46; see also Scott (2013), p. 329.

[80] Rickels et al. (2011), p. 40.

30 However, it must be noted that this method has several disadvantages and is not considered in the same light as the previously discussed methods, primarily due to the associated practicalities, material needs and energy costs. Indeed, an informal meeting concerning space-based solar engineering in November 2019 found that "space-based solar geoengineering is not a plausible near-term goal or aspiration".[81] The main disadvantages associated with this method are that whenever a section of the reflective material is in the Earth's shadow, no radiation would be reflected. Additionally, current predictions indicate that uniform shading caused by the reflective system would be difficult to achieve and, depending on the location of its deployment , the position of the reflector may have to be continuously corrected to fully realise the intended benefits.[82] The use of reflectors in space also comes with several environmental risks, including potentially irreversible damage to the hydrologic cycle as well as the Atlantic deep-water formation.[83] Finally, the material used would need to be of sufficient mass to ensure that it is not immediately pushed out of orbit once deployed—particularly difficult given that there is considerable light-pressure force exerted by the very sunlight such a system is designed to scatter.[84] However, the material requirements to produce sufficient mass for the components of a reflective system naturally results in greater costs for both development and deployment. These many disadvantages resulted in the United States House of Representatives Committee on Space and Technology noting that "due to high projected costs, technological infeasibility and unacceptable environmental and political risks, the solar radiation management (SRM) strategy of space-based mirrors should be a low priority consideration for research".[85]

31 The numerous prohibitive constraints associated with costs, timescales, practicalities and environmental side effects results in an in-depth analysis of this method being unnecessary for this Chapter. Current proposals for this SRM method rely on extensive future technological developments as well as a dramatic reduction in material transport costs.[86] That said, it is important to highlight that the implementation of this method of SRM is different to the previously discussed methods (deployment in space versus atmosphere/surface-based deployment) and the applicable governance regime is therefore predicted to have some notable differences.

[81] Keith et al. (2020).

[82] Rickels et al. (2011), p. 40.

[83] Rickels et al. (2011), p. 40.

[84] Royal Society (2009), p. 32.

[85] U.S. House of Representatives Committee on Science and Technology (2010).

[86] Lawrence et al. (2018), p. 13.

9.3.2 Carbon Dioxide Removal

As with the individual SRM methods examined above, it bears mentioning once more that the risks associated with CDR generally are discussed below (¶ 65 *et seq*) while those risks associated with individual methods are discussed here. CDR methods aim to slow or reverse the current increase in future atmospheric CO_2 concentrations, accelerate the natural removal of atmospheric CO_2, and increase the storage of carbon in land, ocean and geological reservoirs.[87] For this reason, CDR technologies are increasingly referred to as "negative emissions technologies" (NETs) or, as is often the case, the two terms are used synonymously.[88] There appears to be international consensus that NETs are "rapidly becoming a prominent feature of the international climate governance landscape", and CDR methods have already progressed further than SRM methods in that field testing has occurred on a comparably large scale.[89] In response to this, CDR methods have attracted the bulk of the attention of the international community, which has opted in favour of establishing a "moratorium" on large-scale ocean fertilisation, a method that is detailed below (¶ 35 *et seq*). Despite this, however, the IPCC has recently concluded that all "pathways that limit global warming to 1.5 °C with limited or no overshoot project the use of CDR" and that CDR methods will "in most cases achieve net negative emissions to return global warming to 1.5 °C".[90] NETs are also seen by the IPCC as well as the United Nations Environment Programme (UNEP)[91] as important in achieving the climate goals set in the Paris Agreement. This necessitates an understanding of the associated methods (discussed below) as well as detailed knowledge of the gaps in the current governance structure (¶ 71 *et seq*). 32

CDR approaches are based on the fact that CO_2 is naturally sequestered by way of certain physical, chemical and biological processes. The physical processes involved here include either accelerating the ventilation of the ocean by increasing circulation or by directly transporting CO_2 to the deep sea.[92] The chemical processes involve the natural and chemical weathering reaction with rock or soil (i.e. CO_2 becomes bound to minerals in rock and soil, meaning it is removed from the atmosphere).[93] Lastly, the relevant biological processes involve marine phytoplankton on the surface layers of the ocean which, by way of photosynthesis, convert approximately half the Earth's CO_2 into organic carbon. After completion of its life cycle, a small portion of the biomass of marine phytoplankton sinks to great depths or the bottom of the 33

[87] Stocker et al. (2013), p. 98.

[88] McClaren (2012), p. 489.

[89] Craik and Burns (2019), p. 11,114.

[90] Allen et al. (2018), p. 17.

[91] United Nations Environment Programme (UNEP) (2017), p. 65.

[92] Rickels et al. (2011), p. 45.

[93] Rickels et al. (2011), p. 46.

ocean before remineralisation processes transform the organic material into CO_2, nutrients and other chemical forms.[94]

34 With these physical, chemical and biological processes in mind, CDR technologies aim to increase or enhance the natural sequestration of carbon as even a small increase in the ability of natural processes to act as CO_2 reservoirs may result in a large decrease in atmospheric CO_2 content.[95] This can be done in a number of different ways but, for the present Subchapter, those methods associated with biological and physical sequestration are of primary concern since their current governance structures are the most advanced, thereby offering significant insight into any potential geoengineering liability regime. The following Subchapters examine ocean fertilisation (a biological process), artificial upwelling/downwelling (a physical process) as well as carbon capture and storage (also a physical process). Given that many of the CDR methods associated with such processes are ocean-based, it is important to highlight that the governance regime established by the UNCLOS will, to a greater or lesser degree, always be relevant to the CDR methods discussed in this Subchapter.

Ocean Fertilisation

35 The ocean sequesters approximately one-third of anthropogenic CO_2 emissions and is a major carbon sink.[96] The sequestration of carbon by the ocean is done in a number of ways, however, its role as a 'biological carbon pump' is the most pertinent for ocean fertilisation. As a biological process, the carbon pump can be summarised as follows:

> The starting point for this process is the fixation of dissolved inorganic CO2 in shallow ocean waters by phytoplankton in the process of photosynthesis, converting the CO2 into an organic form. While the bulk of fixed organic carbon is remineralized in the upper layers of the ocean and released to the atmosphere, a portion is transported downwards by the sinking of dead phytoplankton biomass and zooplankton fecal pellets into the deep ocean and sediments (i.e., ocean floor). Carbon sinking to the level of sediments can be sequestered for decades to centuries, or even longer.[97]

36 With this process in mind, the aim of ocean fertilisation is to add nutrients to the ocean to increase biological production which, in turn, should increase the "subsequent sequestration in the deep ocean or sea floor sediments" of carbon.[98] It should be noted that ocean fertilisation also refers to methods that are aimed at enhancing fish stocks—i.e. the fertilisation of offshore waters to increase fish numbers.[99] However, this form of ocean fertilisation is not aimed at addressing anthropogenic

[94] Rickels et al. (2011), p. 47.

[95] Rickels et al. (2011), p. 44.

[96] Brent et al. (2019), p. 9.

[97] Brent et al. (2019), p. 10.

[98] de Connick et al. (2018), p. 346; the "biological carbon pump" is defined as the "transport of carbon containing biomass from the surface to the deep ocean" (Rickels et al. 2011, p. 47).

[99] For a detailed discussion of this and other ocean fertilisation methods, see GESAMP (2019), pp. 42–48.

climate change and is, therefore, not considered in this Subchapter as a geoengineering method. Rather, this Subchapter refers to the deliberate fertilisation of the ocean with micronutrients such as iron (ocean iron fertilisation) or macronutrients such as nitrogen and phosphorus. Ocean iron fertilisation seeks to increase iron nutrients available to phytoplankton and thereby increase the amount of carbon that can be exported via the biological carbon pump (more phytoplankton means more dead phytoplankton sinking to the bottom of the ocean).[100] As a geoengineering method, ocean iron fertilisation has generated substantial interest in recent years and is one of the few geoengineering proposals that has progressed to the field testing stage.[101]

Some claims have suggested that increasing the growth of phytoplankton in areas such as the Southern Ocean or the equatorial Pacific (as areas where phytoplankton growth is limited by iron deficiencies), may have the potential to offset as much as 25% of the world's annual carbon emissions.[102] However, more recent assessments have concluded that even large-scale use of ocean iron fertilisation may only sequester "a few gigatons of CO_2 annually, even with fertilisation of the entire Southern Ocean".[103] **37**

The large-scale of the proposed field testing has created considerable environmental concern as ocean fertilisation, whether by micro- or macronutrients, is expected to affect the entire food web since it is primarily aimed at the organisms at the very foundation of that web.[104] Any method that deliberately impacts the food web, thereby modifying systems in the global commons, is likely to have a transboundary impact regardless of its scale of application.[105] Certain studies have also linked ocean fertilisation to accelerated ocean acidification,[106] eutrophication and the production of toxin-producing dinoflagellates.[107] Additional environmental concerns include the fact that extensive and uncontrollable algal blooms will result in dead or oxygen-deficient zones (in both shallow and deep water), which could result in catastrophic consequences for biodiversity.[108] Societal risks associated with ocean fertilisation include the fact that by increasing the growth of phytoplankton, certain downstream ecosystems could be denied critical nutrients which are key to the continued survival of other marine resources, such as fish.[109] Any negative impacts on fisheries will have obvious and potentially dire consequences for the livelihoods of downstream communities and food security. **38**

[100] McGee et al. (2017), p. 68.
[101] McGee et al. (2017), pp. 68–70.
[102] See Brent et al. (2019), p. 10 referencing Powell (2008), p. 4.
[103] Keller (2018), p. 261.
[104] de Connick et al. (2018), p. 346.
[105] Schäfer et al. (2015), pp. 27–28.
[106] Oschlies et al. (2010), p. 4026.
[107] Secretariat of the Convention on Biological Diversity (2009), p. 32.
[108] de Connick et al. (2018), p. 346.
[109] See Brent et al. (2019), p. 11.

39 The long-term effectiveness of ocean fertilisation as a geoengineering method is also questionable with some experts concluding that the extra absorbed carbon would be "returned to the atmosphere relatively rapidly, rather than being transported and stored in the deep ocean or in sea-floor sediments".[110] However, the comparatively advanced scientific understanding of this method, compared to other geoengineering methods, together with the fact that ocean fertilisation has progressed to the field testing stage, has resulted in the establishment of the first geoengineering governance regime (¶ 91 *et seq*). This set of circumstances means that ocean fertilisation necessarily requires consideration in any study assessing the potential liability of geoengineering activities.

Artificial Upwelling/Downwelling

40 As with ocean fertilisation, artificial upwelling aims to stimulate the growth of phytoplankton by providing traditionally nutrient-poor marine regions with additional nutrients.[111] However, unlike ocean fertilisation, nutrient increases are not achieved by physically adding elements (such as iron or nitrogen), rather, artificial upwelling involves pumping large amounts of deeper ocean water (generally rich in nutrients) to the ocean's surface. This stimulates phytoplankton growth and, subsequently, the uptake of CO_2 from the atmosphere.[112] Secondary benefits associated with artificial upwelling include increases in fish production,[113] the cooling of coral reefs[114] and the general cooling of ambient surface waters—potentially countering the effects of global warming at local or regional scales.[115]

41 To date, a wide range of devices have been proposed to enable the upwelling process, including airlift pumps[116] and wave-powered systems,[117] however, artificial upwelling remains controversial and is currently not at the forefront of discussions considering feasible CO_2 removal techniques. There are a number of reasons for this, the first being that "nutrient-rich deeper ocean water is also rich in CO_2, which is brought up to the surface and consequently counteracts the fertilisation effect".[118] The second reason is that any climatic benefits associated with artificial upwelling will require large scale projects involving a very large number of pumps.[119] Additional environmental risks include possible disruptions to the 'ocean thermocline' which will alter cloud cover and atmospheric circulation

[110] Secretariat of the Convention on Biological Diversity (2012), p. 58; see also Royal Society (2009), p. 17.

[111] German Research Foundation (DFG) (2019), p. 35.

[112] German Research Foundation (DFG) (2019), p. 35; GESAMP (2019), p. 61.

[113] See generally Kirke (2003).

[114] See generally Hollier et al. (2011).

[115] GESAMP (2019), p. 61; Brent et al. (2019), p. 11.

[116] For airlift pump systems see Fan et al. (2013), p. 48; see also generally Meng et al. (2013).

[117] For wave powered systems generally see Kenyon (2007) and Fan et al. (2016).

[118] German Research Foundation (DFG) (2019), p. 35.

[119] Secretariat of the Convention on Biological Diversity (2016), p. 65.

patterns, meaning any initial cooling benefits may be followed by an increase in average global temperatures, increased risks of ocean acidification and the restructuring of marine ecosystems.[120]

In contrast to artificial upwelling, the idea behind artificial downwelling is to pump cold surface waters (saturated in CO_2) to the ocean depths.[121] This would allow for 'downwelled' waters to laterally replace "warmer surface waters that subsequently cool and, in this process, take up CO_2 via cooling-enhanced solubility".[122] At present, there is very limited knowledge of the environmental side-effects of downwelling, however, both artificial upwelling and downwelling have been described as having: **42**

> geo-political implications, which are related to where they might be deployed and the scale of the proposed operations. How they would intersect with present day oceanic resource extraction (e.g. fisheries) or proposed marine geoengineering approaches is not known. There is a widespread lack of information for most of these methods, which at present are at the 'drawing board' stage of an initial idea underpinned with some technological [research and development].[123]

Lastly, proposed deployment zones for artificial downwelling include the Arctic Ocean and, since the thickening of ocean ice may be a precursor to increasing successful downwelling, there is reason to believe that this CDR method may be directly or indirectly linked to SRM methods associated with the restoration of sea ice (¶ 25 *et seq*). **43**

Carbon Capture and Storage

Carbon capture and storage (CCS) refers to a variety of different technologies that aim to physically capture carbon from the atmosphere or other CO_2 emitting sources (such as power plants and cement works) and then remotely store such captured CO_2 in human-made or natural reservoirs. Such carbon capture may also be referred to as carbon capture, utilisation and storage (CCUS) when the captured CO_2 is used in other products or services, including enhanced oil recovery. While a thorough review of all available CCS technologies is beyond the scope of the current report,[124] certain similarities can be drawn between all CCS methods. This includes the fact that most CCS projects will be transboundary in nature since any captured CO_2 is likely to be stored in States or locations other than where it was captured and/or **44**

[120] Secretariat of the Convention on Biological Diversity (2016), p. 65; Kwiatkowski et al. (2015), p. 1; and Rickels et al. (2011), p. 46. As far as restructuring marine ecosystems go, Brent et al. (2019, p. 12) conclude that artificial upwelling could "substantially restructure ocean ecosystems, including favouring larger phytoplankton, such as diatoms, and resulting in a shift from oligotrophic (nutrient-poor) to eutrophic (nutrient-rich) species".

[121] GESAMP (2019), p. 63.

[122] GESAMP (2019), p. 63.

[123] GESAMP (2019), p. 24.

[124] Detailed discussion of individual CCS methods can be found in GESAMP (2019), pp. 51–60; German Research Foundation (DFG) (2019), pp. 26–35; and Rickels et al. (2011), pp. 43 *et seq*.

produced.[125] In this regard, the most attractive and often most available options include offshore storage—whether in/on the seabed, or by way of crop wastes and artificial platforms.[126]

45 Notwithstanding this, there is reason to believe that there may be increasing political interest in changing the current international handling of CCS.[127] In this regard, the International Energy Agency identifies CCS as the "only technology available to mitigate greenhouse gas emissions from large-scale fossil fuel usage in fuel transformation, industry and power generation".[128] Similarly, the European Commission has concluded that:

> the 2050 target [part of the EU 2050 Energy Roadmap] can only be achieved if the emissions from fossil fuel combustion are eliminated from the system, and here CCS may have an essential role to play, as a technology that is able to significantly reduce CO_2 emissions from the use of fossil fuels in both the power and industrial sectors.[129]

46 Despite the seemingly positive view held by some towards certain CCS technologies, considerable uncertainty surrounding the feasibility, costs, efficiency and environmental impact of storing CO_2 remotely remains. The environmental risks associated with CCS are dependent on the individual CCS technology under discussion. However, as with many CDR methods, the environmental risks associated with CCS technologies are generally rooted in scientific uncertainty, including their biological impacts (connected to ocean acidification and the altering of deep water ecosystems); the increased need for already under strain natural resources (such as freshwater); the stability of liquid CO_2 on/in the ocean floor; risks to both pelagic and deep-sea fishing (associated with both the storage and transport of captured CO_2); risks to ground and river water chemistry; and the fact that CCS facilitates the continuous dependence on fossil fuels.[130]

47 Unlike SRM methods that are, at this stage, largely dependent on future technology developments, CDR techniques seem to have progressed somewhat further insofar as feasibility studies are concerned. This may, in part, be attributed to the increased discussion surrounding the governance of certain ocean-based CDR methods (¶ 91 *et seq*). However, no CDR method is free of risk, especially considering their potential impact on the marine environment as well as regional and local ecosystems around storage sites.

[125] Langlet (2015), p. 395.

[126] Langlet (2015), p. 395; see also GESAMP (2019), pp. 51–60 for a discussion of different CCS methods.

[127] Langlet (2015), p. 399.

[128] International Energy Agency (IEA) (2013), p. 5.

[129] European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the Future of Carbon Capture and Storage in Europe, COM(2013) 180 Final (Brussels, 2013), p. 11.

[130] GESAMP (2019), pp. 51–60; Langlet (2015), p. 397; Secretariat of the Convention on Biological Diversity (2016), pp. 52–57; Stenzel et al. (2019).

The above has briefly examined a select group of SRM and CDR geoengineering methods, including a brief consideration of their associated and method-specific risks. With this in mind, the following Subchapter highlights the general risks associated with geoengineering as a whole and provides some examples as to what geoengineering damage scenarios may look like. 48

9.3.3 Risks Associated with Geoengineering

In the absence of large-scale field-testing and deployment, geoengineering intervention has, except for ocean fertilisation, remained largely a theoretical prospect. The lack of experience with "real-world" damage events that have occurred as a result of geoengineering has led academia to envisage and analyse damage scenarios that may materialise from such activities in academic literature. Whether or not these scenarios will ever become a reality is, of course, impossible to establish, taking into account the relatively embryonic Stateof most, if not all, geoengineering methods. Therefore, the following Subchapter starts by accepting that geoengineering activities pose numerous risks of varying degrees to the environment and a wide variety of actors at various stages of implementation.[131] For the present Subchapter, the term 'risk' is understood as referring to the potential for a particular geoengineering activity to have adverse consequences which may result in damage, particularly environmental damage. 49

The identified risks raise complex questions associated with social, ethical, legal, environmental and political concerns. However, those risks and damage scenarios associated with the environment are of particular importance in the context of the present liability study. Therefore, to evaluate any international liability regime that may potentially be applicable to geoengineering, the following Subchapter briefly outlines all conceivable risks that may be associated with geoengineering, while focussing particularly on the environmental risks associated with the development and/or eventual deployment of SRM and CDR methods.[132] Whilst focussing on such risks and damage scenarios, this Subchapter nevertheless takes note of the complicated relationship that currently exists between the risks and benefits of one and the same geoengineering method—one method may, for example, pose serious environmental risks but such risks do not exist independently of the benefits that the environment stands to gain from that same method.[133] Additionally, the specific environmental risks associated with some individual methods have already been 50

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[131] This variable risk also includes the scale of at which a particular activity is to be conducted. Large scale field testing and eventual deployment is predicted to cause different and a potentially greater risk of environmental harm than small scale research activities.

[132] Lawrence et al. (2018), p. 5; see also Scheer and Renn (2014), p. 305.

[133] See Heyen (2019), p. 91 where Heyen states that solar geoengineering is part of a broader social debate concerning "how to govern novel technologies that simultaneously hold huge promise and substantial danger".

discussed above. The purpose of this Subchapter is thus to compliment those method-specific risks with the general risks that may impact the establishment of geoengineering liability and governance regimes.

51 Against this background, the following Subchapter first examines a number of the risks and damage scenarios that are generally applicable to geoengineering, be that during or after development and deployment. The risks and damage scenarios mentioned below should be understood as applying, either wholly or partially, to each of the individual SRM and CDR methods described in this study. After highlighting the general risks associated with these specific methods, the environmental risks associated with SRM and CDR, as the two categories of geoengineering, are then briefly discussed.

General Risks Associated with Geoengineering

52 It must be stressed from the outset that all risks associated with geoengineering activities are grounded in scientific uncertainty—that is to say that individual risks associated with geoengineering cannot be separated from the uncertainties within which such risks operate and materialise.[134] Societal, political and other risks are often predicated on the uncertainty surrounding the associated environmental side effects. As research into these side effects advance, it may become clearer which States stand to benefit and which States stand to be more at risk from the deployment of geoengineering techniques. This increasing clarity has the potential to negate continued research into specific geoengineering activities as well as reduce the incentive for States to cooperate in the deployment or development of geoengineering activities generally.[135] However, "no amount of research will reduce uncertainty to zero", and even where net benefits associated with a particular method can be measured, there remains a degree of difficulty in correctly attributing observed changes in the climate system to one specific geoengineering method—especially considering that such a method will be developed or deployed in the presence of other anthropogenic stressors on the climate system (including ocean acidification, pollution and the over-exploitation of natural resources).[136]

53 By way of illustration, consider the following fictional example: The year is 2050 and State A, in an attempt to fulfil its international climate obligations, has recently begun large-scale SAI under the auspices of Project Reduce. Scientists agree that State A should start seeing notable reductions in temperature and precipitation anomalies at a regional level within seven years. State B is known for having volcanic eruptions and has also experienced droughts in the past. Such droughts have never lasted longer than one season and have never occurred more than once every 50 years. State B, located some 2000 kilometres away from State A, protests against the action of State A because climate modellers predict Project Reduce will

[134] See Zeckhauser and Wagner (2019), p. 108 for a general discussion on the relationship between risk and uncertainty in the context of SRM technologies.

[135] Heyen (2019), pp. 92–93.

[136] MacMartin et al. (2019), p. 4.

have a detrimental impact on regional precipitation patterns in State B. Such impacts would adversely affect State B's agricultural industry, which makes up 16% of its GDP. In the wake of what is characterised as "the first drought in 45 years" as well as an increase in volcanic eruptions, State B suffers heavy and unprecedented flooding some six years after the commencement of Project Reduce. Leading up to this event, some climate models suggest that Project Reduce may be altering regional precipitation patterns, whilst other models predict no such link. State B alleges that Project Reduce—ignoring scientific evidence concerning its impact on regional precipitation patterns—is the cause of the flood. For its part, State A alleges that the increased frequency of volcanic eruptions coupled with normal human stressors on the environment is the primary reason for the flooding.

The above example does not present sufficient scientific data to offer a convincing conclusion. However, it demonstrates the problems that may be linked to scientific uncertainty and the difficulties inherent in attributing liability (or a portion thereof) to a specific geoengineering activity. Which international legal regime may govern, or ought to govern, such a scenario is discussed in more detail below (¶ 113 *et seq*). **54**

Given the objectives of this Chapter, it is prudent to shape a primary risk associated with geoengineering in terms of international liability and the concept of scientific uncertainty. Even if a particular geoengineering activity is deployed effectively and marked reductions in the negative effects of climate change are measured, "the salient point from an international law perspective is that geoengineering 'would introduce new risks and would shift the overall burden of risks', and fundamental uncertainties would remain".[137] With this in mind, it is realistic to assume that in deciding on whether and how to use geoengineering techniques, States may disagree as to the potential uncertainties, risks and benefits that may result from a specific geoengineering activity (as in the example above). The relative speed and ease of deploying certain SRM methods in particular may allow individual States—notwithstanding their disagreement with other States over the extent of risks, benefits and uncertainty—to unilaterally deploy or develop a specific activity.[138] Due to this, geoengineering may generally increase the potential for international conflict and, therefore, increase conflicts over issues surrounding liability and compensation.[139] As part of the portfolio of responses to tackle climate change, there is the additional risk that the environmental side effects associated with **55**

[137] See Reichwein et al. (2015, p. 146) busy quoting Irvine et al. (2014), p. 842.

[138] Reichwein et al. (2015), p. 146. Such a situation has the potential to result in a climate "tug-of-war". If State A's ideal temperature points are far removed from those of State B, these two States may implement climate intervention techniques that oppose one another—each State expending resources to cancel out part (or all) of the other's intervention so as to maintain (or attain) their ideal temperature points.

[139] Lawrence et al. (2018), p. 5.

geoengineering could cause novel conflicts and security implications for the international community.[140]

56 The societal risks associated with geoengineering are connected to the dichotomy between negative public perception surrounding the impact of human intervention in the climate system and the potential need to respond to global warming relatively quickly. This becomes particularly salient if at-risk communities and species require swift action to secure their continued existence.[141] The way in which the international community perceives geoengineering necessitates (1) open and transparent discussion surrounding the development/deployment of individual geoengineering methods, (2) building public trust in the institutions involved as well as (3) strong political will to formulate and adhere to robust governance and liability regimes.[142] However, the inherent uncertainty in the scope and nature of the environmental risks associated with geoengineering adds to public scepticism and, ultimately, the extent of its acceptance.[143] Additionally, current governance regimes are scarce and existing mechanisms are either underdeveloped or struggle to find direct application to geoengineering. Another important social risk associated with geoengineering is related to the impact that any large-scale deployment of both SRM and CDR technologies may have on fundamental human rights. Craik and Burns capture this construct in the following manner:

> delivery of a relatively modest three gigatons of CO_2 (GT CO_2) equivalent negative emissions annually would require a land area of approximately 380-700 million hectares in 2100, translating into 7%-25% of agriculture land and 25%-46% of arable and permanent crop area. This level of emissions removal would be equivalent to a startling 21% of total current human appropriated net primary productivity. [. . .] Demands on land of this magnitude could substantially raise food prices on basic commodities. This could imperil food security for many of the world's most vulnerable, with many families in developing countries already expending 70%-80% of their income on food.[144]

Such large-scale operations may threaten the minimum standard of living and right to food guaranteed under various international human rights instruments.[145]

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[140] Maas and Scheffran (2012), p. 193; also Rickels et al. (2011, p. 31) mentioned the geopolitical objections to geoengineering—including that geoengineering methods may "serve as weapons of mass destruction".

[141] For a discussion of the public perception of geoengineering (including Germany in particular), see Rickels et al. (2011), pp. 70–77.

[142] Rickels et al. (2011), p. 71.

[143] For a detailed discussion of some of the ethical risks associated with geoengineering at various stages (including the research/development stage; the large-scale implementation stage; and the post-implementation stage), see University of Montana – Ethics of Geoengineering Online Resource Center (undated).

[144] Craik and Burns (2019), p. 11,114; see also Corry et al. (2019).

[145] See the Universal Declaration of Human Rights, GA Res. 217A(III), Article 25 (1948); the International Covenant on Economic, Social, and Cultural Rights, 16 December 1966, 993 UNTS 3 (entered into force 3 January 1976), Article 11(2); and the Convention on the Rights of the Child, 20 November 1989, 1577 UNTS 3 (entered into force 2 September 1990) Articles 24(2)(c) & (e).

One area of political risk associated with geoengineering is centred on the 'moral hazard debate' and the 'slippery slope argument'. The moral hazard debate proposes that geoengineering will undermine preferred climate mitigation and adaptation efforts.[146] Consequently, the political will to engage in new or already established joint international efforts to achieve emission reductions may be undermined. In other words: **57**

> if individual states signal their preparedness to limit climate change by the deployment of a climate engineering technology, then this could bring with it a reduction in the readiness of other states to exercise control over emissions. Put simply, the "rest" of the world would then rely on those states having [climate engineering] technologies ready to be deployed to limit a rise in temperatures. The "rest" of the world would then correspondingly choose lower efforts to control emissions than would optimally be the case in view of the possible occurrence of serious consequences arising from climate change.[147]

The slippery slope argument, on the other hand, contends that any research into geoengineering has to be in line with existing emission reduction efforts, including relevant international treaties such as the UNFCCC.[148] The concern here is that failure to embed geoengineering research into existing mechanisms risks setting in motion political or economic forces that may influence future national and international decisions to continue and expand geoengineering research, potentially sliding into full-scale deployment, instead of adequately scrutinising the legitimacy of certain geoengineering activities.[149] **58**

The above discussion has highlighted the overarching uncertainties surrounding current geoengineering activities, uncertainties that are compounded by the various techniques available and their specific environmental impacts as well as the variable nature of Earth's climate system in general. Such uncertainties give rise to a number of risks, environmental risks chief amongst them. It must be kept in mind that the above discussion has only highlighted general risks potentially attributable to geoengineering as a whole and that it is impossible to accurately assess and predict every possible risk. In order to complete the discussion on the risks associated with the identified geoengineering methods, the following discussion briefly mentions the environmental risks potentially attributable to both SRM and CDR methods and technologies. **59**

[146] For an examination of the moral hazard debate, see Lin (2013a), p. 673.

[147] Rickels et al. (2011), p. 112.

[148] Rickels et al. (2011), p. 115; United Nations Framework Convention on Climate Change, 9 May 1992, 1771 UNTS 107 (entered into force 21 March 1994) (UNFCCC).

[149] Rickels et al. (2011), pp. 115–119.

Risks Associated with Solar Radiation Management

60 The recent IPCC Special Report on 1.5 °C Global Warming (2018) concludes that although "some SRM measures may be theoretically effective in reducing an overshoot, they face large uncertainties and knowledge gaps as well as substantial risks and institutional and social constraints to deployment related to governance, ethics, and impacts on sustainable development".[150] There are clearly numerous risks associated with SRM technologies and the general risks highlighted above will apply wholly or in part to the development and deployment of all SRM methods. However, given this Subchapter's focus on conceivable, albeit currently still hypothetical, risks and damage scenarios associated with environmental harm, those risks linked to societal, political and/or international peace and security are not discussed further here.[151]

61 Environmental risks include a vast number of direct and indirect impacts associated with scientific uncertainty and the regional specifics under which the implementation of various SRM methods occur as well as the so-called termination problem. While the limited research done into SRM has led to estimates that indicate the time it takes to deploy different SRM methods will vary considerably, the climate system is expected to react relatively quickly once deployment occurs. With this in mind, the Royal Society explains the termination problem—a risk that would persist during the entire period of implementation—by stating that once an SRM method is deployed, the Earth's surface temperatures would return:

> towards their pre-industrial conditions within a few years of deployment, depending on the amount and rate of reduction deployed (since a very rapid reduction might be undesirable). By the same token, however, should such a method, having been implemented for a significant period, subsequently fail or be abruptly stopped, then there would also be a very swift and sustained rise in temperature (an upward 'step', rather than a 'spike') and a rapid transition to the much warmer climate associated with the higher CO_2 levels then pertaining. This is referred to as the 'termination problem', although it cannot be foreseen whether or not such a rapid cessation might ever occur, or under what circumstances.[152]

62 Another environmental risk associated with SRM relates to geographic specifics and, therefore, the impact this has on the uniformity of certain methods. The deployment of a particular SRM method within one region or latitude band (as is the case with SAI, MCB as well as the restoration of ice) has the potential to result in large temperature gradient variations between areas in which such methods are deployed and those where they are not—resulting in, for example, excess cooling

[150] Allen et al. (2018), pp. 12–13.

[151] For a detailed discussion of the additional risks associated with SRM, see the complete studies of the Royal Society (2009), pp. 23–36; Secretariat of the Convention on Biological Diversity (2012); and Stavins and Stowe (2019).

[152] Royal Society (2009), p. 24.

in the tropics or excess warming in higher latitudes.[153] While noting that the international community has been able to agree to hold the average global temperature increase to well below 2 °C above pre-industrial levels, MacMartin et al. have highlighted that while "agreeing on one number is hard, agreeing on multiple goals would be harder still".[154] The variable impacts on regional temperatures that may be caused by SRM methods will require States to independently manage multiple goals while acknowledging that "it will not be possible to design a deployment that can achieve every possible goal in every region of the world, and the trade-offs involved will require the ability to agree on more complex choices than simply a number".[155] It is evident that the impacts of certain methods are unlikely to be uniform and certain methods may, therefore, pose significant and undesirable risks to biodiversity as well as to rare and/or fragile ecosystems.

There is also evidence that a reduction in global temperatures will decrease "plant respiration rates and therefore increase [the] net CO_2 uptake by the land biosphere", resulting in "entirely new environmental conditions with impacts on biological systems".[156] In this regard, increased CO_2 levels (affecting land primary productivity and river runoff) may have negative consequences for marine ecosystems due to ocean acidification.[157] **63**

All the above potential risks take place in the overarching context of scientific uncertainty. In relation to SRM methods, such uncertainty includes the fact that an 'SRM world' introduces a new dynamic in that the heating effects of greenhouse gases and the cooling effects of sunlight reduction would exist simultaneously. The stability and impact of high concentrations of greenhouse gases in combination with a reduction in light quantity remain uncertain and underdeveloped.[158] Additionally, there is prevailing agreement that for the effectiveness of SRM methods to be adequately measured, large-scale field tests will be required.[159] Such a conclusion is relevant for two reasons. First, the international rules and principles usually associated with research and development, which are precaution-oriented and traditionally require initial research to be done on a small testing scale, may be inadequate if testing SRM via large-scale deployment/implementation causes significant harm. Second, large-scale field testing may be indistinguishable from what could be characterised as the gradual initiation of SRM technology.[160] With this in mind, it bears mention that a number of academics have recently advocated for an "International Non-Use Agreement on Solar Geoengineering", calling for: **64**

[153] Royal Society (2009), p. 34; see also Secretariat of the Convention on Biological Diversity (2012), pp. 26 & 45.

[154] MacMartin et al. (2019), p. 10.

[155] MacMartin et al. (2019), p. 10.

[156] Royal Society (2009), p. 34.

[157] Caldeira and Wickett (2003); see also Royal Society (2009), p. 34.

[158] Secretariat of the Convention on Biological Diversity (2012), pp. 26 & 46.

[159] Robock et al. (2010).

[160] Royal Society (2009), p. 39.

> immediate political action from governments, the United Nations and other actors, such as civil society organizations, to forestall further normalization of solar geoengineering as a future climate policy option. Governments and the United Nations need to take effective political control and restrict the development of solar geoengineering technologies.[161]

As a final note to the foregoing, it should be remembered that all SRM methods, while having the potential to rapidly reduce average global temperatures, do not reduce CO_2 and other greenhouse gas concentrations in the atmosphere.

Risks Associated with Carbon Dioxide Removal

65 Despite several recent studies on CDR technologies generally, there remains limited research into the direct impact that NETs may have on ecosystems and biodiversity. For this reason, the environmental risks of CDR enumerated here are discussed in terms of their climatic effectiveness, agricultural impacts and other indirect impacts. The variable nature of different CDR methods, including whether such methods are deployed on land or at sea, means that the following discussion only highlights some of the risks particular to CDR and does not represent an exhaustive list. Furthermore, the general risks associated with geoengineering that were discussed above also apply to CDR methods either wholly or in part.

66 As with SRM methods, the IPCC Special Report on 1.5 °C Global Warming (2018) also highlights that the risks associated with CDR methods are accentuated by scientific uncertainty. In this regard, the IPCC concludes that limitations "to our understanding of how the carbon cycle responds to net negative emissions increase the uncertainty about the effectiveness of CDR to decline temperatures after a peak".[162] The uncertainties surrounding the effectiveness of negative emissions technologies complicates any understanding of the numerous environmental risks that already surround such technologies. Many concerns associated with CDR methods centre around the fact that their potential benefits are generally slow-acting, may eventually prove to be only modestly beneficial or even ineffective and the environmental damage they cause may occur before any benefits are ever realised.[163] Human intervention in natural biological and chemical processes may have unintended consequences for both biodiversity as well as various ecosystems. These consequences for ecosystems will potentially be amplified when methods are used in particularly vulnerable areas, such as ocean iron fertilisation being used in the fragile Southern Ocean ecosystem. With respect to ocean-based CDR methods, a significant side-effect of increasing oceanic carbon uptake is the associated dissolution of CO_2 in water and the corresponding acidification of the oceans.[164] As atmospheric CO_2 concentrations have increased, surface waters have already

[161] Biermann et al. (2022), p. 4.

[162] Allen et al. (2018), p. 34.

[163] Secretariat of the Convention on Biological Diversity (2012), p. 54; see also Keller et al. (2018), p. 1135, where the authors state that "the technical ability of CDR methods to remove such enormous quantities of CO_2 on relatively short timescales (i.e., this century) is doubtful".

[164] Rickels et al. (2011), p. 44.

become more acidic. However, if methods such as ocean fertilisation (¶ 35 *et seq*) or those that involve the sequestration of carbon in the ocean (¶ 40 *et seq*) are deployed, this effect could be reversed since the acidity of the surface ocean would decrease as CO_2 is removed from the atmosphere. Instead, the main problem associated with ocean-based CDR methods is that acidification will occur where the CO_2 is stored (generally at great depths where both the ecosystems and the impacts are largely unknown).[165]

Negative Emissions Technologies: Fictitious Damage Scenario **67**

The 'Nautilus' is a German flagged and government-funded research vessel that has recently begun a cooperative ocean iron fertilisation project in the high-seas region of the Pacific Ocean off the coast of South America. Together with Ecuador's support, the Nautilus is set to disperse 250 tons of iron dust over a 10,000-square-kilometre area in order to facilitate a phytoplankton bloom in an area that is known to have iron deficiencies. The experiment is part of the German government's ongoing research into assessing whether substantial CDR projects have the potential to meet global climate stabilisation objectives. There is scientific evidence to suggest that the project will not only increase the uptake of atmospheric CO_2 in the region but also the amount of marine life surrounding the Galapagos Archipelago.

Approximately one year after the Nautilus released the iron dust, Ecuador reported an increase in the number of fish around the Galapagos Archipelago and scientists measured slight decreases in local atmospheric CO_2. However, Colombia claims that the geoengineering experiment has resulted in a loss of fish in a river that borders Ecuador and Colombia, resulting in food security concerns and economic loss to local fishing communities. Some 1,000 kilometres away, Panama reports an unprecedented increase in toxin-producing dinoflagellates which resulted in the temporary closure of the Panama Canal.

There is some scientific evidence that suggests the reason for the reduction in freshwater fish in the river bordering Ecuador and Colombia is the same reason for the unprecedented dinoflagellates in the Panama Canal. Some other scientific models suggest that, given the flow patterns in the Pacific Ocean, the ocean fertilisation experiment conducted by the Nautilus may have resulted in the dinoflagellates in the Panama Canal, however, it is doubtful whether the experiment had any impact on freshwater fish in regional rivers.

The above scenario highlights important questions that can arise as to where and how to attribute liability for environmental damage; how to define damage in the context of methods such as ocean iron fertilisation; the extent to which damage can **68**

[165] Rickels et al. (2011), pp. 44–45.

be apportioned to cooperating but not deploying States (Ecuador in this case); and the rights of third States (such as Panama) affected by an alleged breach of international obligations, such as that to protect and preserve the marine environment.

69 Additional challenges surrounding current negative emissions technologies include difficulties inherent to establishing and quantifying environmental damage. Such challenges are exacerbated by the fact that most CDR methods are being studied and classified in isolation while there is currently limited discussion on the potential environmental effects that may result due to interactions between methods or "between multiple instances of the same techniques".[166] Being able to attribute liability for environmental damage caused by specific CDR deployment will require detailed understanding and knowledge of the potential interactions between CDR methods that often take place within the same broad environmental context, as in the case with those that are ocean-based. Other environmental risks include the fact that several CDR methods, especially land-based methods, are water and other-resource intensive endeavours that may conflict with Sustainable Development Goals (SDGs) associated with the conservation of natural resources.[167] Lastly, although CDR methods reduce atmospheric CO_2, greenhouse gas emission levels are unaffected and successfully storing captured CO_2 will have to overcome environmental hazards associated with issues such as "salinization through the permeation of saline water into aquifers and [the] acidification of drinking water".[168] In the broader context of stabilising the climate, the "climatic benefits of [removing atmospheric CO_2] are likely to be negated through further fossil fuel combustion and CO_2 release" associated with processes such as enhanced oil recovery.[169]

70 The risks, be they environmental, ethical, social, political or otherwise, associated with various geoengineering activities are all currently shrouded in uncertainty. For this Subchapter, such uncertainties allow two tentative conclusions to be drawn: first, identifying all the potential side effects and quantifying the damage that each risk poses to the Earth's natural and societal systems is not possible. Second, such uncertainties do not automatically and generally preclude, or even discourage, the use of geoengineering methods. Rather, uncertainty arguably necessitates accepting the plethora of associated risks which will need to be managed by developing a far-reaching and dynamic governance regime where its effectiveness will largely be determined by its ability to hold responsible actors liable. With this in mind, the following Subchapter highlights the current regulatory regime applicable to geoengineering methods. It is important to note that the aim of this analysis is not to make a comprehensive assessment of the international legality or illegality of geoengineering. Rather, it serves to provide clarity for the aggregated results obtained in other relevant studies to provide the basis for a thorough examination into what an effective geoengineering liability regime may include.

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[166] GESAMP (2019), p. 28.

[167] Umweltbundesamt (2019).

[168] Umweltbundesamt (2019).

[169] Secretariat of the Convention on Biological Diversity (2016), p. 49.

9.4 Current Regulatory Landscape for Existing Geoengineering Methods

The primarily transboundary and partly global character of geoengineering necessitates that the legality of individual geoengineering methods is examined in accordance with the rules and principles of public international law. Following this, any legal assessment of geoengineering must both consider and, for the purposes of regulation, differentiate between the sources of international law, including international treaties and customary international law. In the context of a study dedicated to liability, understanding the regulatory framework is necessary since the parameters of what is classified as a legal activity constitutes a necessary starting point for evaluating both State responsibility, in cases where an activity violates prescribed regulations or laws, and liability in cases where environmental damage results despite the potential absence of a breach of international laws or regulations. **71**

No international convention has ever been adopted for the specific purpose of regulating geoengineering.[170] Virtually all regimes providing regulation and international governance of geoengineering methods currently contain no norms specifically developed with the research and deployment of such methods in mind. Indeed, the only exception to this is the 2013 Amendment to the London Protocol (¶ 93 *et seq*). The fact that geoengineering activities are nonetheless to a greater or lesser degree addressed by existing international agreements is partly attributable to the framework approach consistent with international law-making. This is particularly the case in the context of global environmental issues associated with areas such as ozone, climate and biodiversity protection.[171] In this regard, framework conventions commonly contain general principles and rules, where generality is overcome by annexes to the convention or in subsequently adopted protocols. This often allows the rules and principles captured in the framework convention to be applied to new phenomena that were unknown when the treaty was first negotiated. This ability of international law to adapt is particularly relevant in this context as many of the implementation risks and opportunities associated with geoengineering will likely be quite different when realised from what is currently understood using today's research models.[172] For this reason, any application of existing international law will have to consider the extent to which such international laws are capable of adapting to and governing what are, at present, somewhat abstract technologies with **72**

[170] Proelss (2012b), p. 205. In this regard, Schäfer et al. (2015), p. 89, highlights that due to "(1) the time it would take to negotiate [a geoengineering specific] instrument, (2) that 'commons-based' and 'territorial' climate engineering techniques raise different jurisdictional issues and would thus require different forms of international cooperation and decision-making, and (3) that a clear sense is yet to emerge of what the interests of different actors may be", it seems both unlikely and undesirable that a single international instrument to regulate a variety of different methods under the general term "geoengineering" will, at this stage, be established.

[171] Proelss (2012b), p. 205; see also Rickels et al. (2011), p. 85.

[172] Brent et al. (2019), p. 17.

unforeseen outcomes. Over and above identifiable treaty-based obligations, any activity that poses a significant risk of harm to the environment is also subject to the broader rules and obligations found within international environmental law generally. Such rules and obligations applicable to the purposes of geoengineering may include the precautionary principle; the duty to cooperate (including the related duties associated with negotiation and information exchange); the principle of prevention; the obligation to undertake environmental impact assessments (EIAs); the principle to give due regard to other users; and the rules regarding State responsibility.[173]

73 The ensuing discussion on the legal regime applicable to geoengineering proceeds with two specific points in mind: (1) there is neither a comprehensive treaty regime in place nor an overarching legally binding definition of geoengineering, and the legality of any geoengineering method must, therefore, be judged according to each technology and based on the international rules and principles specifically applicable to it; (2) taking into account the general objective to limit global average temperature rise to well below 2 °C above pre-industrial levels, and in the absence of any prohibition or moratorium vis-à-vis geoengineering generally, international law cannot be held to be generally opposed to geoengineering research and deployment.[174]

74 With these points in mind, this Subchapter first examines conventions and instruments that are or could potentially apply to geoengineering. This discussion also includes a brief mention of the currently ongoing negotiations surrounding biological diversity in areas beyond national jurisdiction as an additional avenue for governing geoengineering in the marine environment (¶ 103 *et seq*). Following this, the applicability of a select number of customary international law rules is examined (¶ 105 *et seq*). The Subchapter concludes with a discussion of existing customary and instrument-specific international law which sets the foundation for the following Subchapter's analysis of the responsibility and liability for geoengineering activities that may cause damage (¶ 113 *et seq*).

9.4.1 Specialised International Instruments (Potentially) Applicable to Geoengineering

75 At the fourth session of the United Nations Environment Assembly (UNEA) in March 2019, the Swiss government put forward a draft proposal requesting a limited role for the United Nations Environment Programme (UNEP) in preparing "an

[173] For a general discussion on some of these rules and obligations, particularly in relation to their applicability to geoengineering methods, see Scott (2013), pp. 333–350.

[174] Note though, the 10th COP to the CBD has often been referenced as imposing a general moratorium on research into and the deployment of geoengineering technologies (see Sikka 2020, p. 101).

assessment of the status of geoengineering technologies, in particular, carbon dioxide removal technologies and solar radiation management".[175] After it became evident that there was insufficient support from those States present, Switzerland withdrew the proposal.[176] Craik and Burns argue that this failure to engage with the topic of geoengineering is proof that there is currently "little appetite for new international initiatives on [climate engineering]" while Corry questions whether this reaction has resulted in the global governance of geoengineering stumbling at the first hurdle.[177] This lack of engagement seems to suggest that greater emphasis needs to be placed on existing as well as new and more specific governance regimes to regulate both the research and potential deployment of individual geoengineering methods. With this in mind, geoengineering activities must be measured against the requirements of those treaties that are, depending on the factual situation, particularly affected and with the proviso that the State of origin is a party to them.[178]

There are a number of relevant international instruments which may play a direct 76
or indirect role in the governance of geoengineering activities, especially considering that many of them codify various international environmental law principles applicable in various temporal spaces, namely the atmosphere, ocean or on land. The following discussion on the existing legal framework that may govern geoengineering must be read in the context of two specific points. First, the below discussion speaks of governance in general, however, it is important to remember that no CDR or SRM methods are currently being conducted other than small-scale field experiments. Additionally, the regimes discussed below are, to a greater or lesser extent, applicable to the governance of both the pre-deployment stages (research and development) and actual deployment of geoengineering methods.[179] Second, despite the absence of regimes established for the specific purpose of regulating geoengineering, the framework nature of international law-making mentioned above provides that even new phenomena are captured by the existing instruments, and, for this reason, geoengineering does not take place within a "legal black hole".[180] The following discussion first analyses specialised

[175] Corry et al. (2019) and Switzerland (2019).

[176] Corry et al. (2019).

[177] Craik and Burns (2019), p. 11,114; Corry et al. (2019).

[178] Proelss (2012b), p. 207. Note that according to the principle *pacta tertiis nec nocent nec prosunt* codified in Article 34 of the Vienna Convention on the Law of Treaties (VCLT), which is also recognised as customary international law, third States are not bound by a treaty to which they have not consented.

[179] In this regard, parallels could be drawn between the current exploration phase taking place within the context of deep seabed mining. This exploration phase (primarily for the purposes of research and understanding the risks and benefits that deep seabed mining presents) is a precursor to the exploitation phase where large-scale mining activities may potentially be implemented (see Annex D). With regards to solar geoengineering research governance specifically, Reynolds (2019a) states that "current solar geoengineering decision-making concerns not deployment but instead – for example – establishing and detailing norms, facilitating responsible and effective research, minimizing any harmful displacement of emissions abatement and preventing undue lock-in".

[180] Scott (2013), p. 330.

international instruments applicable to all geoengineering proposals, with those instruments specific to either SRM or CDR methods being emphasised as necessary. The Subchapter ends with a brief mention of the ongoing negotiations surrounding biodiversity beyond national jurisdiction to understand the potential future implications for marine geoengineering governance.

International Climate Change Regime

77 With 197 States parties, the 1992 UNFCCC is the primary legal instrument regulating the protection of the Earth's climate and is, therefore, an appropriate starting point for evaluating current regulatory regimes vis-à-vis their applicability to geoengineering. The ultimate aim of the UNFCCC is to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the global climate system.[181] As a framework convention, the UNFCCC contains broad obligations mainly limited to procedural requirements associated with obligations to document and communicate information concerning emissions, national policies and best practices. In line with any framework convention, the UNFCCC is given more impetus by both the 1997 Kyoto Protocol[182] as well as the 2015 Paris Agreement.

78 The Kyoto Protocol, in operationalising the objectives of the UNFCCC, requires that the industrialised States listed in Chap. 11 of the UNFCCC ensure that their greenhouse gas emissions do not exceed the individually determined reduction commitments contained in Annex B to the Protocol itself.[183] Article 3(3) of the Kyoto Protocol provides two strategies to achieve the goal of stabilising atmospheric concentrations of greenhouse gases required under the UNFCCC, namely the reduction of greenhouse gas emissions at source and the removal of greenhouse gases through sinks. Relevant for the Kyoto Protocol and the present discussion is Article 1(8) of the UNFCCC, which defines a sink as "any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere". This definition covers geoengineering activities that are associated with greenhouse gas removal, most notably CDR methods. [184] For this reason, the objective of the UNFCCC does not seem to preclude the deployment of most CDR methods as these may serve as mechanisms to support the UNFCCC's overall objective, however, the UNFCCC's objectives appear "incompatible with SRM methods that do not seek to reduce atmospheric concentrations of CO_2".[185]

79 Other potentially applicable UNFCCC provisions include Articles 3(1) and 3(3) which deal with the principle of common but differentiated responsibilities

[181] UNFCCC Article 2.

[182] Kyoto Protocol to the United Nations Framework Convention on Climate Change, 11 December 1997, 2303 UNTS 162 (entered into force 16 February 2005) (Kyoto Protocol).

[183] Rickels et al. (2011), p. 87.

[184] Schäfer et al. (2015), p. 84; Proelss (2012b), p. 208; Du (2019), p. 44; Craik and Burns (2019), p. 11,122; Reynolds (2018), p. 67.

[185] Scott (2013), p. 330; see also Winter (2011), pp. 280–281.

and respective capabilities as well as the precautionary principle respectively. Additionally, Article 4(1)(c) may also play a role in the active removal of greenhouse gases by calling on States parties to promote and "cooperate in the development, application and diffusion, including transfer of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases". These relatively general guidelines could be particularly relevant in regulating geoengineering activities in those cases where no specific regulation exists.[186] Lastly, it is worth noting that together with the Kyoto Protocol, the UNFCCC also creates a notable institutional structure for governing the Earth's climate and that the climate change secretariat already cooperates with both the CBD secretariat as well as the secretariat of the UNCCD[187] on "mutually supportive activities".[188]

Any contemporary assessment of the current climate change regime potentially applicable to geoengineering would be incomplete without mention of the 2015 Paris Agreement. The Paris Agreement is not a protocol as defined in Article 17 of the UNFCCC, however, it does have some of the same basic requirements, including the fact that only States parties to the UNFCCC may be parties to the Paris Agreement.[189] Under the Kyoto Protocol, the emission reduction commitments are tied to a specific time frame, the first of which has expired and the second of which is yet to enter into force.[190] Conversely, the Paris Agreement's 'core obligations' do not expire and require that States commit to certain processes and targets. Therefore, the Paris Agreement, unlike the Kyoto Protocol's period-based commitments, provides for a continuous and ongoing process of national submissions for climate action.[191] Pursuant to this, the Paris Agreement sets specific 'climate criteria' with the aim that States limit global temperature increase to well below 2 °C, ideally pursuing efforts to limit the increase to 1.5 °C, and establishes binding commitments for all States parties to prepare, communicate and maintain nationally determined contributions (NDCs).[192] In this regard, States parties "shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions".[193] It should be stressed that the "key substantive elements [of the Paris Agreement] are determined at the discretion of each State and, once set, remain political not legal commitments". [194] The Contracting parties to the Paris Agreement are not legally **80**

[186] Proelss (2012b), p. 208.

[187] United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa, 14 October 1994, 1954 UNTS 3 (entered into force 26 December 1996).

[188] Royal Society (2009), p. 41.

[189] Paris Agreement, Article 20(1); Craik and Burns (2019), p. 11,117.

[190] Craik and Burns (2016), p. 4.

[191] Sands and Peel (2018), p. 299.

[192] Paris Agreement Articles 2(1)(a) and 4.

[193] Paris Agreement Article 4(2).

[194] Craik and Burns (2019), p. 11,117.

obliged to achieve the NDCs which they have set for themselves,[195] and it is arguably also not possible to 'apportion' the average temperature goal to be achieved on the global level among the Contracting parties in the sense of an individual obligation or result.[196]

81 Other important points to keep in mind concerning geoengineering and the governance regime established by the Paris Agreement include the fact that although geoengineering techniques are not expressly incorporated into the approaches to address climate change, certain CDR methods may have to be integrated into the Paris Agreement's central mechanisms to achieve the Agreement's central aims.[197] This is because Article 1 of the Paris Agreement incorporates the definitions in Article 1 of the UNFCCC, including the definitions of 'sinks' mentioned above, and 'reservoirs'.[198] Given that these definitions are not restricted to naturally occurring processes,[199] this may include certain CDR technologies. Additionally, it seems that, like the UNFCCC, SRM technologies are largely outside the scope of the Paris Agreement and "do not appear to be easily amenable to [its] structure and approach".[200] However, the procedural and institutional mechanisms of the Paris Agreement "may provide some opportunity to inform the Parties on the current status of [SRM] research, including its potential to address climate impacts and the associated risks of experimentation and deployment".[201] This is especially true since SRM methods are aimed at responding to the negative effects of climate change and Articles 7 and 8 frame such responses as being the "collective responsibility" of States parties.[202] The extent to which either CDR or SRM methods will be regulated by the Paris Agreement rests on the decisions adopted by the Meeting of the Parties to the Paris Agreement, the central decision-making body tasked with implementing the Agreement.[203] Lastly, it is particularly important in the present context to mention that Article 8, which deals with loss and damage and specifically refers to the Warsaw International Mechanism for Loss and Damage, does not include liability and compensation. The decision that accompanied the adoption of the Paris Agreement in 2015 expressly states that Article 8 "does not involve or provide

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[195] Mayer (2018), p. 135; Rajamani (2020), p. 169.

[196] Voigt (2016), p. 27.

[197] Paris Agreement Article 1 read with Articles 4 & 5.

[198] 'Reservoir' means a component or components of the climate system where a greenhouse gas or a precursor of a greenhouse gas is stored (UNFCCC Article 1(7)).

[199] Craik and Burns (2019), p. 11,122.

[200] Craik and Burns (2019), p. 11,128.

[201] Craik and Burns (2019), p. 11,129. In this regard, see also a recent report commissioned by the Swiss Federal Office for the Environment which highlights that the UNFCCC could contribute to the governance of SRM since, amongst other things, the UNFCCC's scope could be interpreted liberally by focusing on its calls to protect the climate system (Arts 3(1) and 3(4) UNFCCC); SRM could help keep global warming within the Paris Agreement's temperature goals and an amendment or protocol could broaden the UNFCCC's objective (Reynolds 2020).

[202] Craik and Burns (2019), p. 11,125.

[203] Paris Agreement Article 16(4); see also Craik and Burns (2019), p. 11,127.

a basis for any liability or compensation".[204] This decision resulted in several States submitting declarations (in accordance with Article 20(3) UNFCCC) when ratifying the Paris Agreement that the Agreement does not exclude the applicability of general rules of international law, including those associated with State responsibility and liability.[205]

The general structure of the international climate change governance regime, the risk preferences of individual States parties, the exclusion of liability and compensation from the Paris Agreement coupled with the various approaches to geoengineering represent a challenging mix of factors. This mix may prove difficult when it comes to coherently managing geoengineering, assuming the current climate change regime can do so at all, and further drives the need to establish an international liability regime for damage caused as a result of geoengineering activities. This is seemingly already being recognised as geoengineering has been a part of the agendas of several climate policy discussions[206] and the UNFCCC, together with the Paris Agreement, may prove to be the most obvious frameworks within which States could attempt early and effective governance of certain geoengineering techniques.[207] **82**

The ENMOD Convention

The United Nations Convention on the Prohibition of Military or Any Hostile Use of Environmental Modification Techniques (ENMOD)[208] is probably the instrument most pertinent to geoengineering in terms of its specific subject matter.[209] Article II of ENMOD defines "environmental modification techniques" 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". At first glance, this definition seems broad enough to include several geoengineering activities which are, by their very nature, activities that intervene in natural processes. However, Article I of ENMOD limits the environmental modification techniques that are covered by the convention to those that are used for military or hostile purposes. This, coupled with the intention of the parties not to address the question of "whether or not a given use of environmental modification techniques for peaceful purposes is in accordance with **83**

[204] UNFCCC Decision 1/CP.21, Adoption of the Paris Agreement, UN Doc FCCC/CP/2015/10/Add.1 (29 January 2016) para. 51.

[205] These States included the Cook Islands, the Federated States of Micronesia, Nauru, the Philippines, Solomon Islands and Tuvalu (see https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27#EndDec, accessed 1 Apr 2022, for a list of declarations made when ratifying the Paris Agreement). See also Toussaint (2020), pp. 4 & 8.

[206] As can especially be seen in the IPCC's assessment reports discussing both CDR and SRM geoengineering methods (see Ciais et al. 2013, pp. 546–552).

[207] Lawrence et al. (2018), p. 13.

[208] 1976 United Nations Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, 10 December 1976, 1108 UNTS 151 (entered into force 5 October 1978) (ENMOD Convention).

[209] Scott (2013), p. 332.

generally recognized principles and applicable rules of international law",[210] results in the conclusion that ENMOD is not applicable to geoengineering. This conclusion applies even in cases where the risks associated with geoengineering, environmental or otherwise, materialise into real-world problems, especially given the convention's close connection to the concept of armed conflict which is decisive for the applicability of international humanitarian law.[211]

United Nations Convention on the Law of the Sea

84 UNCLOS enjoys broad support and engagement in its efforts to regulate all ocean space by attaining a balance between the various rights and obligations owed to and by a multitude of actors.[212] Despite the fact that a handful of States have not yet ratified UNCLOS, including the USA, many of its provisions have been accepted as reflecting customary international law. Like the Convention on Biological Diversity discussed below, UNCLOS has far-reaching application and may offer both direct and indirect opportunities to regulate various geoengineering activities, including ocean iron fertilisation, marine cloud brightening and methods associated with the restoration of ice in the polar regions. The UNCLOS framework is supplemented by a large number of regional and international instruments to deal with a variety of issues, including environmental protection, shipping and holding States as well as other actors responsible and/or liable for any harm caused. However, given the far-reaching ambit of UNCLOS and the various rights and obligations contained therein, a detailed analysis is beyond the scope of the current study.[213] Instead, the following Subchapter differentiates between ocean space beyond and within national jurisdiction to highlight the framework nature of UNCLOS and mentions those rights and obligations which may find general application to ocean-based geoengineering activities.

85 The international law of the sea is founded on the principle of the freedom of the high seas. As an area beyond the jurisdiction of any State, the high seas cannot be made subject to any State's claims of sovereignty (Article 89) and all States are entitled to exercise the non-exhaustive list of freedoms codified in Article 87 UNCLOS. In this regard, the freedom of navigation and the freedom of scientific research are particularly relevant to geoengineering activities.[214] Given that the freedoms codified in Article 87 are not an exhaustive list, any activity that is not prohibited and does not compromise the reservation of the high seas for peaceful purposes (Article 88) may be subject to the freedom of the high seas principle. Consequently, any geoengineering activity taking place in, on or under the high seas

[210] UN GAOR 1976, Report on the conference of the Committee on Disarmament, Vol. I, 91, Supplement No. 27, 31st Session (A/31/27); see also Rickels et al. (2011), p. 86.

[211] Proelss (2012b), p. 208.

[212] Scott (2015), p. 462.

[213] For a detailed analysis of the UNCLOS and marine geoengineering see Rickels et al. (2011), pp. 92–97; Scott (2015), pp. 462 *et seq*; and Brent et al. (2019).

[214] Rickels et al. (2011), p. 93.

is arguably subject to the same freedom.[215] However, this freedom is not absolute, inasmuch as States using the high seas must have due regard for the interests of other States (Article 87(2)). Such qualification of due regard is particularly relevant for geoengineering activities that the placement of ocean pipes or other structures, or that involve the injection of iron into the ocean, or the injection of sea salt particles above the ocean—may hinder the freedom of fishing or navigation, or that could cause pollution. Any geoengineering activity must therefore have due regard for other UNCLOS obligations, including those concerning the Area (Part XI),[216] the protection and preservation of the marine environment (Part XII) and marine scientific research (Part XIII). As such, these obligations may arguably limit the ability of States to conduct large-scale geoengineering activities on the high seas.[217]

Concerning geoengineering activities that take place in coastal State waters, **86**
States benefit from having exclusive jurisdiction over marine scientific research within their territorial sea, as a part of the territory of the State,[218] and within their exclusive economic zone (EEZ).[219] This means that coastal States can "consequently control the extent and nature of any marine geoengineering research they choose to carry out or authorize" in such maritime zones.[220] However, certain geoengineering methods, including MCB's dispersal of sea salt particles to form low-level clouds over the ocean, have been identified as falling outside the scope of what is classified as marine scientific research and the deployment of vessels tasked with such sea salt dispersal in another State's EEZ is, therefore, not subject to the consent of the coastal State.[221] The reason is that such activities, even when performed on an exploratory basis, do not increase knowledge about the marine environment—a mandatory requirement for any activity to qualify as marine scientific research.[222] Whether classified as marine scientific research or not, all geoengineering activities that take place on the high seas are subject to the principle of due regard.[223]

[215] Scott (2015), p. 462.

[216] Article 1(1) UNCLOS defines the Area as "the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction".

[217] Scott (2015), p. 462.

[218] Article 245 UNCLOS states that "[c]oastal States, in the exercise of their sovereignty, have the exclusive right to regulate, authorize and conduct marine scientific research in their territorial sea. Marine scientific research therein shall be conducted only with the express consent of and under the conditions set forth by the coastal State". For a detailed discussion in this regard, see Huh and Nishimoto (2017).

[219] According to Article 246 UNCLOS, "[c]oastal States, in the exercise of their jurisdiction, have the right to regulate, authorize and conduct marine scientific research in their exclusive economic zone and on their continental shelf" and that marine scientific research "in the exclusive economic zone and on the continental shelf shall be conducted with the consent of the coastal State".

[220] Scott (2015), pp. 462–463; see Articles 56(b)(ii), 245 & 246 UNCLOS.

[221] Proelss (2015), pp. 291–294.

[222] Proelss (2015), p. 293. See generally Matz-Lück (2017), para. 13; Soons (1982), p. 124.

[223] As far as EEZs are concerned, it has been suggested by Proelss and Hong (2012), p. 377, that Article 59 UNCLOS applies to any marine geoengineering activities which have left the experimental phase and are carried out for the purpose of CDR. This provision covers economic uses other

87 In this context, brief mention should be made of the ICJ's decision in the *Whaling Case*.[224] Although this case did not deal with geoengineering, it did deal with an interpretation of the term 'scientific research' which may have future implications for the classification of certain geoengineering activities as scientific research, particularly at their research/development stage. In this case, Australia alleged that Japan's whaling programme in the Southern Ocean (JARPA II) was not for the purposes of scientific research but a guise for commercial whaling.[225] Japan, for its part, argued that that the programme constituted scientific research under Article VIII of the International Convention for the Regulation of Whaling (ICRW).[226] Without providing a definition of 'scientific research', the ICJ ruled that:

> an objective test of whether a programme is for purposes of scientific research does not turn on the intentions of individual government officials, but rather on whether the design and implementation of a programme are reasonable in relation to achieving the stated research objectives. [. . .] The research objectives alone must be sufficient to justify the programme as designed and implemented.[227]

88 Following the ICJ's ruling that JARPA II was not for the purposes of scientific research, Japan subsequently withdrew from the ICRW in July 2019.[228] This discussion is important in the present context for two reasons: First, it is an indication of the inherent difficulty in "policing the distinction between scientific research and other types of activity".[229] This is an issue to keep in mind when developing a regulatory regime for geoengineering as the regime's effectiveness will depend on its acceptance by a large number of States. Second, the ICJ's finding in the *Whaling Case* may have implications for the Assessment Framework for Scientific Research Involving Ocean Fertilization under the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention) and the 1996 London Protocol (¶ 92 *et seq*). In this regard, certain ocean fertilisation activities may be classified as 'scientific research' and, objectively, may fulfil their stated research objectives (as per the ICJ's reasoning in the *Whaling Case*).

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than those mentioned in Articles 56(1) and 58(1) as well as other non-economic uses of an EEZ. Given that Article 59 constitutes a conflict rule rather than assigning sovereign rights or jurisdiction to any of the groups of States concerned, activities covered by its terms are, in absence of a user conflict, generally to be considered as lawful.

[224] ICJ *Whaling in the Antarctic* (Australia v Japan; New Zealand Intervening) [2014] ICJ Rep 226 [the *Whaling Case*].

[225] ICJ *Whaling in the Antarctic* (Australia v Japan; New Zealand Intervening) [2014] ICJ Rep 226, para. 130.

[226] ICJ *Whaling in the Antarctic* (Australia v Japan; New Zealand Intervening) [2014] ICJ Rep 226, para. 49; International Convention for the Regulation of Whaling, 2 December 1946, 161 UNTS 72 (entered into force 10 November 1948) [ICRW].

[227] ICJ *Whaling in the Antarctic* (Australia v Japan; New Zealand Intervening) [2014] ICJ Rep 226, para. 97.

[228] Ministry of Foreign Affairs of Japan (2018).

[229] Brent et al. (2019), p. 21.

However, whether such activities will be viewed as 'legitimate scientific research' for the purposes of the London Convention/London Protocol remains to be seen. Needless to say, the harmonious application of the freedom to conduct marine scientific research as guaranteed in the UNCLOS with the London Convention's/London Protocol's current ban on ocean fertilisation activities for any reason other than legitimate scientific research would be desirable when establishing a uniform geoengineering governance framework.

Convention on Biological Diversity

With 196 States parties, the Convention on Biological Diversity (CBD) enjoys nearly universal adherence and has been interpreted as forming "part of the corpus of general international law".[230] The CBD is a multilateral environmental treaty whose broad mandate, strong institutional support and near-universal participation means that parties to the convention have the opportunity to address a wide range of projects that may have an impact on the environment.[231] Tasked with protecting and conserving biodiversity, the various environmental impacts associated with geoengineering are clearly matters that fall under the scope of the CBD. In this regard, the CBD has dealt with geoengineering governance in the form of several decisions taken at the conference of the parties (COP), particularly the 2008 decision on ocean fertilisation,[232] the 2010 decision on climate engineering,[233] several decisions adopted in 2012 related to geoengineering[234] and the 2016 reaffirmation of previous climate engineering decisions.[235] To a greater or lesser degree, all of these decisions have concretised the notion that: **89**

> in the absence of science based, global, transparent and effective control and regulatory mechanisms for geo-engineering, and in accordance with the precautionary approach and Article 14 of the Convention, that no climate-related geo-engineering activities that may affect biodiversity take place, until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts, with the exception of small scale scientific research studies that would be conducted in a controlled setting in accordance with Article 3 of the Convention, and only if they are justified by the need to gather specific scientific data and are subject to a thorough prior assessment of the potential impacts on the environment.[236]

[230] PCA *South China Sea Arbitration* (Philipines v China) (2016) 33 RIAA 1, para. 956 [*South China Sea Arbitration*].

[231] Reynolds (2017), p. 809.

[232] COP to the CBD, IX/16 Biodiversity and climate change, UNEP/CBD/COP/DEC/IX/16 (9 October 2008) (CBD IX/16).

[233] COP to the CBD, X/33 Biodiversity and climate change, UNEP/CBD/COP/DEC/X/33 (29 October 2010) (CBD X/33).

[234] COP to the CBD, XI/20 Climate-related geoengineering, UNEP/CBD/COP/DEC/XI/20 (5 December 2012) (CBD XI/20).

[235] COP to the CBD, XIII/14 Climate-related geoengineering, CBD/COP/DEC/XIII/14 (8 December 2016) (CBD XIII/14).

[236] CBD X/33, para. 8(w); see also CBD XI/20, para. 1; CBD XIII/14, para. 1.

90 Notwithstanding the controversial question of whether or not these decisions must be taken into account as interpretative aids when interpreting the CBD,[237] they are relevant for two specific reasons: First, the COP of the CBD has addressed geoengineering generally, coupled with the broad mandate given to the COP (Article 23(4)(i) CBD) and the potential environmental impacts described above, suggest that the CBD is relevant to all activities currently being discussed under the umbrella term 'geoengineering'.[238] Second, the near-universal acceptance of the CBD conveys the strong political will to engage in further discussion on the governance and regulation of geoengineering at the international level[239] even though the COP seems to have assumed an increasingly reserved role on geoengineering-related issues in recent years. Such international discussions will be grounded on the principles enunciated in the Convention, including the obligation to cooperate in areas beyond national jurisdiction and on other matters of mutual interest, for the conservation and sustainable use of biodiversity (Article 5) as well as the obligation to conduct EIAs where a project is likely to result in significant adverse effects to biodiversity (Article 14). Thus, the decisions of the CBD's COP, together with its broad mandate, could guide the future regulation of geoengineering activities that may have adverse impacts on biodiversity.

London Convention and Protocol

91 The general aim of both the London Convention and the London Protocol is that all practicable steps are taken to prevent pollution by the dumping of waste and other matter into the sea.[240] It must be noted that the Protocol is not a 'traditional international protocol' since it will eventually replace the London Convention.[241] It provides a more restrictive approach to the regulation of dumping than the Convention by generally prohibiting all forms of dumping.[242] In 2006, it was amended to include CO_2 streams from CO_2 capture processes for storage to the list of wastes or other matter that may be considered for dumping. Furthermore, in 2009 a new paragraph was added to Article 6 of the Protocol which has made it possible to export carbon dioxide streams for disposal in accordance with Chap. 11.[243] It is also worth mention in this context that the Protocol also directly

[237] For a new assessment see Proelss (in print). In the *Whaling Case*, the ICJ made the following pertinent statement: "These recommendations, which take the form of resolutions, are not binding. However, when they are adopted by consensus or by a unanimous vote, they may be relevant for the interpretation of the Convention or its Schedule" (ICJ *Whaling in the Antarctic* (Australia v Japan; New Zealand Intervening) [2014] ICJ Rep 226, para. 46).

[238] Bodle (2010), p. 314.

[239] Schäfer et al. (2015), p. 113.

[240] Article I London Convention; Article 2 London Protocol.

[241] Article 23 London Protocol.

[242] This is subject to limited exceptions on the so-called 'reverse list' (Article 4 London Protocol).

[243] Resolution LP.3(4) of 30 October 2009 on the Amendment to Article 6 of the London Protocol.

incorporates the precautionary approach, which was not accepted when the London Convention was adopted.[244]

Whether the introduction of substances are to be qualified as pollution of the marine environment under the London Convention and/or Protocol must be judged on the effects that such substances have on the marine environment rather than the substances' characteristics.[245] This is especially pertinent in the case of ocean fertilisation as well as carbon capture and storage (CCS) because their potential to have adverse impacts could lead these activities to be classified as the deliberate disposal at sea of wastes and other matter which, as such, qualifies them as dumping.[246] In response to ocean fertilisation specifically, the States parties to the London Convention and the London Protocol initially expressed concern about the activity's environmental impacts in 2007 and, in 2008, adopted Resolution LC-LP.1 agreeing that ocean fertilisation activities, other than those for legitimate scientific research, "should be considered as contrary to the aims of the Convention and Protocol and do not currently qualify for any exemption from the definition of dumping".[247] In Resolution LC-LP.2(2010), the States parties went one step further and adopted an Assessment Framework for Scientific Research Involving Ocean Fertilization which "provides criteria for an initial assessment of a proposal and detailed steps for completion of an environmental assessment, including risk management and monitoring".[248] In 2014, the ILC concluded in the context of its work on subsequent agreements and practice in relation to the interpretation of treaties that "the Conference of States Parties [sic!] under the London (Dumping) Convention has adopted resolutions interpreting that convention",[249] and that "interpretative resolutions by Conferences of States Parties which are adopted by consensus, even if they are not binding as such, can nevertheless be subsequent agreements under article 31, paragraph 3 (a), or subsequent practice under article 31, paragraph 3 (b) [VCLT]".[250] In short, Resolution LC-LP.1 expressly recalls the objectives of the London Convention and Protocol in its Preamble and that it introduces, as stated above, a distinction between "legitimate scientific research" and other (i.e., non-legitimate) research that 92

[244] Article 3.1 London Protocol obliges States parties to "apply a precautionary approach to environmental protection from dumping of wastes or other matter" and this article will consequentially be amended to include "placement of matter for marine geoengineering activities which may be considered for permits according to annex 4" when the marine geoengineering amendments come into force (see the discussion below on the 2013 amendments to the Protocol); see also GESAMP (2019), p. 91.

[245] Rickels et al. (2011), p. 94.

[246] See Article III(1) London Convention and Article 1(4) London Protocol.

[247] Resolution LC-LP.1(2008) of 31 October 2008 on the Regulation of Ocean Fertilization.

[248] Resolution LC-LP.2(2010) of 14 October 2010 on the Assessment Framework for Scientific Research Involving Ocean Fertilization.

[249] UN Doc A/69/10, Report of the International Law Commission on the Work of its Sixty-Sixth Session (2014), Chapter VII, Commentary to Draft Conclusion 10, para. 12.

[250] UN Doc A/69/10, Report of the International Law Commission on the Work of its Sixty-Sixth Session (2014), Chapter VII, Commentary to Draft Conclusion 10, para. 38.

is further substantiated by Resolution LC-LP.2(2010). Given this, the argument can be made that the two resolutions can be relied upon as interpretative tools under Article 31(3) VCLT to make it possible for the responsible authorities of the Contracting parties to decide whether an ocean fertilisation experiment can be authorized or not.

93 In 2013, the meeting of the parties of the London Protocol adopted several amendments to the Protocol which provide the first step towards legally binding regulation of ocean fertilisation and, at least potentially, marine geoengineering in general.[251] However, with only six acceptance instruments currently deposited with the International Maritime Organization (out of the two-thirds of States parties required for adoption), the 2013 amendments are yet to enter into force.[252]

94 Despite this current lack of legal effect, a few brief points regarding the 2013 amendments are worth noting. First, for the first time in an international instrument, the 2013 amendments introduce a definition of 'marine geoengineering' (Article 1(5) *bis*) that is broad enough to include various geoengineering methods rather than just ocean fertilisation.[253] Second, the 2013 amendments introduce a geoengineering regulatory framework which stipulates that States "shall not allow the placement of matter into the sea from vessels, aircraft, platforms or other man-made structures at sea for marine geoengineering activities listed in Chap. 13, unless the listing provides that the activity or the subcategory of an activity may be authorized under a permit" (Article 6*bis*). Consequently, Article 6*bis* creates the presumption that geoengineering is not permitted, subject to those limited exceptions which are agreed upon by the States parties and listed in Chap. 13. Third, the regulatory framework instituted by Article 6*bis* is limited to the "placement of matter into the sea" and the extent to which SRM methods associated with the placement of reflective material *onto* (as opposed to *into*) the sea are covered by its terms is highly questionable.[254] The same applies with regard to methods that use "the oceans as a tool from which to effect geoengineering but which do not involve the placement of matter therein", as in the case of marine cloud brightening.[255]

[251] Resolution LP.4(8) of 18 October 2013, Amendment to the London Protocol to Regulate the Placement of Matter for Ocean Fertilization and other Marine Geoengineering Activities. The Amendment is included as Annex 4 in LC 35/15. For an initial assessment see Ginzky and Frost (2014), pp. 82 *et seq;* see generally also Boschen (2015); and Ringbom et al. (2018), pp. 59–63.

[252] With 53 States currently party to the London Protocol, 36 States would need to ratify the 2013 amendment for it to be adopted. The most recent acceptance instrument for the 2013 amendment was deposited by Germany in March 2020.

[253] The Article 1(5)*bis* of the 2013 Amended London Protocol amendment (not yet in force) defines marine geoengineering as "a deliberate intervention in the marine environment to manipulate natural processes, including to counteract anthropogenic climate change and/or its impacts, and that has the potential to result in deleterious effects, especially where those effects may be widespread, long lasting or severe".

[254] Scott (2015), p. 459.

[255] Scott (2015), p. 459; see also Proelss (2015), pp. 291–294. However, see the rather dubious and unfounded view taken in GESAMP (2019), p. 23, stating that the "deposition of salt particles on the ocean surface [could constitute] a deposit of 'wastes or other matter' under the [London Protocol]".

Lastly, it is also worth mentioning that the 2013 amendments, the London Convention and the London Protocol all fail to define what is meant by 'legitimate scientific research'. That said, the 2013 amendments do make specific reference to the Assessment Framework adopted in 2010 which "provides a tool for assessing proposed activities on a case-by-case basis to determine if the proposed activity constitutes legitimate scientific research that is not contrary to the aims of the London Convention or Protocol".[256] However, given the previously discussed (¶ 92 *et seq*) difficulties in distinguishing between scientific research and other legitimate types of activities, the lack of a specific definition of scientific research in both the Convention and the Protocol, even in the latter's 2013 amendment, is regrettable. Related to this last issue is the fact that the 2010 Assessment Framework, as referred to in the 2013 amendments, is only applicable to the governance of geoengineering research but not to its large-scale deployment.[257] Given the difficulty in distinguishing between large-scale field testing and what could be characterised as the gradual initiation of a certain geoengineering activity, the parameters of what would classify as 'legitimate scientific research' will need to be developed further in future. **95**

Despite agreement by the Contracting parties to regulate ocean fertilisation and, at least potentially, marine geoengineering more generally, the same agreement has not been forthcoming with regards to the development of procedures concerning responsibility and liability. Both the London Convention and the Protocol make specific reference to responsibility and liability, with Article X of the London Convention stating that: **96**

> In accordance with the principles of international law regarding State responsibility for damage to the environment of other States or to any other area of the environment, caused by dumping of wastes and other matter of all kinds, the Contracting Parties undertake to develop procedures for the assessment of liability and the settlement of disputes regarding dumping.

The equivalent in the London Protocol is found in Article 15 which states that:

> In accordance with the principles of international law regarding State responsibility for damage to the environment of other States or to any other area of the environment, the Contracting Parties undertake to develop procedures regarding liability arising from the dumping or incineration at sea of wastes or other matter.

Over the years, liability issues have repeatedly been considered by specific groups, as can be seen in the examples of the 'ad hoc group of legal experts on dumping' and the 'Task Team on Liability'. However, disagreements persist concerning the role of civil liability schemes versus a State liability regime, the assessment of the damage resulting from dumping as well as time limitations for the operator's liability and the related question of obtaining insurance cover on **97**

[256] GESAMP (2019), p. 82.
[257] GESAMP (2019), p. 78.

the market.[258] In 2018, the consultative meetings of the Contracting parties of both the Convention and the Protocol "considered whether the absence of a specific liability regime for LC/LP constituted a barrier to accession and/or harmonised implementation of the treaties and whether there was a need for the governing bodies to develop such procedures".[259] Consequently, at the meeting in 2019, numerous options were noted for consideration including (1) nonbinding liability procedures since neither the Convention nor the Protocol obligate States to develop a separate liability protocol or binding procedures; (2) the relevant existent principles of State responsibility that could guide future discussions of the governing bodies and be used as a basis for the development of a State liability regime or procedures regarding liability; and (3) recourse to existing dispute settlement procedures such as those described in Article 16 of the London Protocol.[260] Recent meetings have highlighted that establishing international liability procedures could lead to "increased transparency for third parties and the public, access to information, public participation, and access to justice for victims of pollution and eventually be an incentive for further accessions".[261] However, despite continued inclusion on the meeting agendas, the establishment of procedures related to liability and responsibility under the London Convention and Protocol continues to elude the Contracting parties.

98 Given that the 2013 amendments have yet to enter into force, the London Convention and the Protocol (without its 2013 amendments) remain the applicable legal regime for ocean pollution caused by dumping. The provisions of these instruments must be read in conjunction with Part XII UNCLOS which distinguishes between different types of pollution and designates corresponding legal obligations for each.[262] In view of the fact that the fertilisation of a specific marine area could

[258] International Maritime Organization, Any Other Business: Liability Issues (Note by the Secretariat), 41st Consultative Meeting of Contracting Parties to the London Convention & 14th Meeting of Contracting Parties to the London Protocol. Doc. No. LC 41/15 (2019), pp. 2–4. See also de La Fayette (1998); de La Fayette (2003), p. 232; Chen (2012).

[259] International Maritime Organization, Report of the Forty-first Consultative Meeting and the Fourteenth Meeting of Contracting Parties, 41st Consultative Meeting of Contracting Parties to the London Convention & 14th Meeting of Contracting Parties to the London Protocol. Doc. No. LC 41/17 (2019), p. 49; see also Birchenough and Haag (2020), p. 276.

[260] International Maritime Organization, Report of the Forty-first Consultative Meeting and the Fourteenth Meeting of Contracting Parties, 41st Consultative Meeting of Contracting Parties to the London Convention & 14th Meeting of Contracting Parties to the London Protocol. Doc. No. LC 41/17 (2019), p. 50. Interestingly, the Meeting noted that the Advisory Opinion of ITLOS (ITLOS *Request for an Advisory Opinion Submitted by the Sub-Regional Fisheries Commission (SRFC)* (Advisory Opinion), 2 April 2015, ITLOS Report 2015, 4) could be applied by analogy and Article 16 of the London Protocol could then be used to settle a dispute arising from the breach of an obligation under the Protocol.

[261] International Maritime Organization, Any Other Business: Liability Issues (Note by the Secretariat), 41st Consultative Meeting of Contracting Parties to the London Convention & 14th Meeting of Contracting Parties to the London Protocol. Doc. No. LC 41/15 (2019), p. 6.

[262] Article 210(6) UNCLOS; see Rickels et al. (2011), p. 94.

also be seen as dumping, Article 210 UNCLOS comes into consideration as the pertinent protection norm. Article 210(1) obligates States to adopt regulations to "prevent, reduce and control pollution of the marine environment by dumping", which must be "no less effective [. . .] than the global rules and standards" (Article 210(6)). Article 210(6) UNCLOS has been accepted as referring to both the London Convention and the London Protocol,[263] while the adoption of the 2013 amendments may bring ocean fertilisation, and potentially other marine geoengineering activities, directly under the purview of the UNCLOS.

The above said, it appears that for the immediate to medium-term future, States will not be subject to any specific marine geoengineering regime established by the London Convention and Protocol. However, given the broad definition of 'marine geoengineering' provided in the 2013 amendments, the London Protocol seemingly offers more potential for future geoengineering governance than any other existing international instrument. The Protocol took ten years to come into force and it would seem realistic that the 2013 amendments will itself take some time to enter into force.[264] In the meantime, however, the general obligations associated with environmental protection and marine scientific research, especially as found in the UNCLOS, will continue to (indirectly) govern geoengineering activities taking place in and around ocean space. **99**

Legal Regime for Outer Space

The legality of installing reflectors in outer space (¶ 29 *et seq*) is judged according to the international treaties governing the protection and use of outer space, particularly the 1967 Outer Space Treaty.[265] This treaty applies to all SRM methods that aim to reduce solar radiation with reflectors or mirrors that are placed at a distance of more than 120 km from the Earth. This, according to the accepted view of where outer space starts, puts all such objects in outer space rather than in airspaces subject to the sovereignty of States.[266] Article I (1) of the Outer Space Treaty qualifies the research and use of outer space as the "province of all mankind" and any State's geoengineering activity in outer space may therefore not adversely impact other States. Such adverse impacts include environmental damage that may be caused as a result of unintended climate consequences associated with the **100**

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[263] LEG/MISC/3/Rev.1, 6 January 2003, Implications of the Entry into Force of the United Nations Convention on the Law of the Sea for the International Maritime Organization, p. 48; agreeing Wacht (2017), para. 20. However, see Churchill and Lowe (1999), p. 369, interpreting Articles 210 to 216 UNCLOS as incorporating the standards set out in the Convention rather than the Protocol (and therefore not the amendments); see also Proelss (in print), stating that it would seem to be questionable whether it can really be assumed that the States parties to the UNCLOS intended to include in the Convention such a broad reference to future developments, which are, as far as States that decide *not* to participate in these developments are concerned, completely beyond their control.

[264] GESAMP (2019), p. 21.

[265] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space Including the Moon and Other Celestial Bodies, 27 January 1967, 610 UNTS 205 (entered into force 10 October 1967) (Outer Space Treaty).

[266] Rickels et al. (2011), p. 87.

deployment of space-based solar reflectors, damage to orbital assets as a result of collisions; or damage caused as a result of such reflectors falling from space back to Earth.[267] The liability which may result if any of these scenarios come to pass is regulated by the Space Liability Convention, which is discussed elsewhere in this book (Chap. 11).

101 Article IX of the Outer Space Treaty further restricts SRM activities in outer space as it requires that States parties conduct research in and use outer space in a way that avoids "harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter". The stipulation that all "harmful contamination" of outer space is to be prevented applies not just to the contamination itself but also includes every negative modification of outer space, the moon and other celestial bodies. At which point a modification can be qualified as negative is a matter of ongoing interpretation and a full discussion of this is beyond the scope of this study.[268] That having been said, Article IX does contain elements of precaution, even though the precautionary principle was unknown in international law at the time the Outer Space Treaty was adopted in the 1960s. The central characteristics of this principle, namely scientific uncertainty, environmental hazard and a duty to consult, can be identified in Article IX. For this reason, particular attention should be paid to the effects of the precautionary principle (¶ 110 *et seq*) in the context of potential SRM activities in outer space.[269]

Convention on Long-Range Transboundary Air Pollution

102 The lawfulness of introducing reflective aerosols or other particles into the stratosphere for various SRM technologies should be assessed based on, *inter alia*, the Convention on Long-Range Transboundary Air Pollution (CLRTAP).[270] CLRTAP has 51 States parties and was negotiated in the 1970s when increasing air pollution and acid rain were particularly salient issues. While this background may prompt the assumption that the CLRTAP does not have direct legal implications for geoengineering, the 'open' character of its norms provides latitude for its potential application to certain SRM activities. Article 2 CLRTAP states that parties "shall endeavour to limit and, as far as possible, gradually reduce and prevent air pollution". Accompanying this, air pollution is defined in Article 1(a) as the "introduction by man [. . .] of substances or energy into the air", which not only includes sulphur particles but also all other particles and aerosols which are being discussed for introduction into the stratosphere.[271] Furthermore, Article 1(a) CLRTAP also states that the materials being introduced must result "in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems and

[267] Sands and Peel (2018), p. 290.

[268] For an overview see Rickels et al. (2011), pp. 88–89.

[269] Rickels et al. (2011), p. 89.

[270] Convention on Long-Range Transboundary Air Pollution, 13 November 1979, 1302 UNTS 217 (entered into force 16 March 1983) (CLRTAP).

[271] Proelss (2012b), p. 207.

material property and impair or interfere with amenities and other legitimate uses of the environment". CLRTAP thus requires that a negative impact results from the introduced substances for them to be qualified as air pollution. It should be noted that the 'deleterious effects' must reach a certain threshold, the 'endangerment' a certain magnitude and the effects must have already occurred.[272] While such negative consequences of certain SRM methods, specifically SAI, cannot be excluded,[273] CLRTAP contains no indication that the potential to cause damage would be sufficient for the substances used to be classed as pollutants. Due to the lack of reference to features of precaution, it is thus necessary that adverse effects on the environment must be proven for the CLRTAP to be applicable. This becomes somewhat problematic as such evidence may be available for some substances under discussion for atmospheric dispersal, SO_2 for example, but not for others.

Ongoing Negotiations Surrounding Biodiversity Beyond National Jurisdiction

The ongoing negotiations regarding an international legally binding instrument under the UNCLOS on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (BBNJ) require brief mention. Although this instrument has not yet been formally adopted, it presents an opportunity to examine how relevant actors make use of specialised treaty instruments to develop rules, including indirect rules, applicable to geoengineering—specifically marine geoengineering in this case. This is evidenced by several statements made during preparatory committee meetings. In this regard, the African Group indicated in 2016 that marine geoengineering activities that take place on the high seas should automatically be subject to EIAs.[274] This sentiment was built on by the High Seas Alliance, which argued that any EIAs relating to geoengineering activities should be subject to an international decision-making process under the BBNJ Agreement.[275] Whilst a thorough assessment of the content of this agreement is beyond the scope of the present study, the current draft text includes climate change as a consideration when defining the 'cumulative impacts' which must be taken into account when conducting EIAs. As far as marine geoengineering is concerned, this has led commentators to state that the development of new rules under the BBNJ Agreement has the potential to be "overly restrictive and prevent responsible research and development of marine geoengineering".[276] However, it should be noted that even under current customary law, the inclusion of potential negative impacts of ocean-related activities must always be considered in the context of EIAs. Any failure to do so would not be compatible with the central principles of international environmental law, in particular, the principles of prevention and precaution (¶ 105 *et seq*). 103

[272] Reynolds (2019b), p. 98.

[273] Proelss (2012b), pp. 207–208.

[274] International Institute for Sustainable Development (IISD) (2016).

[275] International Institute for Sustainable Development (IISD) (2017).

[276] Brent et al. (2019), p. 51.

104 None of the above-identified treaties provides clear answers as to the legality of individual geoengineering methods, perhaps with the exception of ocean iron fertilisation. However, most treaties seem to indicate that those activities which are likely to have a negative impact, be that environmental or otherwise, should be considered unlawful by the respective State parties. This should be done in accordance with the terms of the specific agreements concerned and after consideration of the impacts of the specific method being proposed. Having considered specialised treaties and their level of applicability to geoengineering, the next Subchapter briefly examines customary international law in a geoengineering context.

9.4.2 Rules and Principles of Customary International Law

105 With regards to customary international law and geoengineering, the obligation not to cause significant transboundary harm, namely the prohibitive dimension of what is referred to as the 'no harm rule', and the principle of prevention require specific mention.[277] The relationship between these two concepts has a somewhat intricate history. That said, the principle of prevention has generally been accepted as containing a duty of conduct rather than one of result, which obligates a State undertaking an activity to take measures to prevent transboundary harm and thus to act with due diligence.[278] In the context of geoengineering, States are similarly required to act with due diligence and any failure to do so may result in the responsibility of that State (¶ 115 *et seq*). Reference can be made here to the ITLOS SDC advisory opinion which describes the due diligence obligation as variable and susceptible to "change over time as measures considered sufficiently diligent at a certain moment may become not diligent enough in light, for instance, of new scientific or technological knowledge. It may also change in relation to the risks involved in the activity".[279] Therefore, as research into certain geoengineering methods advances, the threshold of due diligence may increase or decrease accordingly.

106 The obligation not to cause significant transboundary harm was originally elaborated on in the *Trail Smelter Arbitration* which held that "no State has the right to use or permit the use of territory in such a manner as to cause injury [. . .] to the territory of another".[280] It has been argued by commentators that the *Trail Smelter*

[277] Saxler et al. (2015), p. 122.

[278] ICJ *Pulp Mills on the River Uruguay* (Argentina v Uruguay) [2010] ICJ Rep 14, para. 101; Boyle and Redgwell (2021), pp. 163–167; Viñuales (2020), pp. 116–117. A similar duty of conduct, and therefore an associated duty to act with due diligence, can be found in the liability regime discussed above in relation to deep seabed mining under Part XI UNCLOS (see Annex D of this book).

[279] ITLOS *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area* (Advisory Opinion), 1 February 2011, ITLOS Report 2011, 10, para. 117. For analysis see Papanicolopulu (2020), pp. 152–154.

[280] *Trail Smelter Case* (United States v Canada) (1941) 3 RIAA 1905, 1965.

Arbitration established a duty of result which has not been referred to in international case law since.[281] In contrast, the ILC seems to have acted on the premise that the decision in the *Trail Smelter Arbitration* did not address a separate obligation not to cause significant transboundary harm as it only relied on what is today called the principle of prevention.[282] Both positions indicate that no duty of result can be applied to cases of transboundary damage and that the no harm concept is thus arguably limited to the obligations deriving from the principle of prevention.[283] It may thus be reasoned that a State which causes transboundary harm by conducting a certain activity can generally not be held responsible based on customary international law if it has acted with due diligence.[284] In this regard, international courts and tribunals have interpreted the prevention principle, having its origins in the obligation of due diligence, as including certain procedural obligations concerned with EIAs and the duties to consult and notify.[285] The ICJ in the *Certain Activities Case* went a step further by recognising a preliminary obligation to ascertain the risks involved, an obligation that needs to be fulfilled prior to conducting an EIA.[286]

Given the potentially severe consequences that may arise from the deployment or **107**
large-scale field tests of most, if not all, geoengineering methods, such 'preliminary risk assessment' seems to indicate that every geoengineering activity will be subject to an EIA. However, it has to be highlighted that although recognition of this need to conduct an EIA as a customary international law obligation is welcome, international jurisprudence has fallen short in providing guidance as to what the minimum content of such an assessment should entail.[287] By leaving the determination of the content to the discretion of individual States, the customary international law requirement to conduct an EIA appears to have "no real substantive content".[288] This is particularly problematic given that the current understanding of geoengineering and its impacts are grounded in scientific uncertainty, which may be more or less acceptable

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[281] Proelss (2012a), p. 621. For in-depth discussion see Krieger and Peters (2020), pp. 356–362.

[282] ILC Draft Articles on Prevention of Transboundary Harm from Hazardous Activities with Commentaries, Yearbook of the International Law Commission Vol. II Part Two (2001), p. 148, General Commentary, para. 4.

[283] For an in-depth assessment see Brunnée (2020), pp. 115–162; see also Proelss (2017a), pp. 81–84.

[284] Consenting Brunnée (2020), pp. 150–153, clarifying that "[w]hether or not transboundary harm is caused matters, of course, but *not* because harm is an element of the primary obligation. Rather, it is relevant in assessing the consequences of a breach of the preventive duty" (157).

[285] ICJ *Certain Activities Carried Out by Nicaragua in the Border Area* (Costa Rica v Nicaragua) *and Construction of a Road in Costa Rica along the San Juan River* (Nicaragua v Costa Rica) [2015] ICJ Rep 665, para. 168; ICJ *Pulp Mills on the River Uruguay* (Argentina v Uruguay) [2010] ICJ Rep 14, para. 204; see generally Brent et al. (2015).

[286] ICJ *Certain Activities Carried Out by Nicaragua in the Border Area* (Costa Rica v Nicaragua) *and Construction of a Road in Costa Rica along the San Juan River* (Nicaragua v Costa Rica) [2015] ICJ Rep 665, para. 153.

[287] ICJ *Pulp Mills on the River Uruguay* (Argentina v Uruguay) [2010] ICJ Rep 14, para. 205; see also Saxler et al. (2015), p. 123.

[288] Sands and Peel (2018), p. 679.

depending on the specific requirements set for EIAs by the governing domestic legislation.[289]

108 In this context, mention should also be made of the recent ILC Draft Guidelines on the Protection of the Atmosphere (Atmosphere Guidelines). Provisionally adopted by the ILC in May 2021, Guideline 7 states that:

> Activities aimed at intentional large-scale modification of the atmosphere should only be conducted with prudence and caution, and subject to any applicable rules of international law, including those relating to environmental impact assessment.

109 The commentaries to the Atmosphere Guidelines make evident that 'activities' in the context of Guideline 7 should be understood as referring to geoengineering, including those technologies classified as either CDR or SRM.[290] The commentaries to Guideline 7 also make clear that it does not seek to "authorize or to prohibit such activities" but acknowledges that any benefit generally must be balanced with the potentially "unexpected effects on existing climatic patterns that are not confined by national boundaries".[291] While legally non-binding, the specific reference to activities aimed at intentional large-scale modification of the atmosphere in the Atmosphere Guidelines of the ILC provides yet another example of the variable nature of due diligence as well as the difficulty in establishing standardised criteria to identify breaches of a State's due diligence obligations.

110 In addition to the principle of prevention, the precautionary principle must be taken into account as it has been encapsulated in various international instruments already mentioned, such as the London Protocol, the UNFCCC and the UNCLOS. At its most general level, the precautionary principle means that States:

> agree to act carefully and with foresight when taking decisions that concern activities that may have an adverse impact on the environment. A more focused interpretation provides that the principle requires activities and substances, which may be harmful to the environment, to be regulated, and possibly prohibited, even if no conclusive or overwhelming evidence is available as to the harm or likely harm they may cause to the environment.[292]

111 The following discussion accepts that there is considerable disagreement concerning the principle's acceptance as either an 'approach' or a 'principle',

[289] Although the adequacy of domestic legislation may be evaluated in assessing whether or not a State has fulfilled its due diligence obligations (see PCA *South China Sea Arbitration* (Philipines v China) (2016) 33 RIAA 1, para. 990 in this regard).

[290] UN Doc. A/76/20 (2021), Report on the Work of the ILC of the Seventy-second Session, Chapter 4: Draft Guidelines on the Protection of the Atmosphere, https://legal.un.org/ilc/reports/2021/english/chp4.pdf, accessed 1 Apr 2022, 33 (Commentary to Guideline 7, para. 3).

[291] UN Doc. A/76/20 (2021), Report on the Work of the ILC of the Seventy-second Session, Chapter 4: Draft Guidelines on the Protection of the Atmosphere, https://legal.un.org/ilc/reports/2021/english/chp4.pdf, accessed 1 Apr 2022, 34 (Commentary to Guideline 7, paras. 7 & 9).

[292] Sands and Peel (2018), p. 234.

however, a consideration of this discussion is beyond the scope of this report.[293] Notwithstanding this, the precautionary principle may prove to be a fundamental component in decision-making processes that involve the implementation and development of geoengineering. This is a realistic view as geoengineering activities are still subject to uncertainty and have the potential for significant detrimental environmental impacts.[294] The ITLOS SDC has acknowledged the growing acceptance and application of the precautionary approach by referring, first, to its intrinsic link to a State's due diligence obligation and, second, by highlighting an international "trend towards making this approach part of customary international law".[295]

As with the specific international instruments examined above (¶ 75 *et seq*), customary international law finds general application to all geoengineering activities. However, the lack of accepted minimum requirements for EIAs, the variable nature of the due diligence obligation (intrinsically linked to the customary international law obligation not to cause significant transboundary harm) and the uncertainties surrounding the validity, content and legal effects of the precautionary principle/approach results in the conclusion that the relevance of the norms of customary international law in assessing liability or responsibility for geoengineering activities should generally not be overestimated.[296] With this in mind, the next Subchapter looks at the potential responsibility and liability that may materialise as a result of damage caused by geoengineering activities. **112**

9.5 Responsibility and Liability for Damage Caused by Geoengineering Activities

Proposals to develop and deploy geoengineering technology call into question the capability of international law to adequately govern and regulate innovative and contemporary technologies.[297] To incentivise the behaviour of States, as well as other actors, any legal framework for geoengineering will have to encompass distinct **113**

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[293] Reference to the term 'approach' instead of 'principle' is preferred by commentators who argue in favour of a more flexible handling of environmental risks, the occurrence of which is subject to scientific uncertainty. However, this understanding can arguably not be held to be reflected in binding international law; see Boyle and Redgwell (2021), pp. 172–173; Proelss (2017a), p. 89.

[294] Scott (2015), p. 463; Proelss (2017a), pp. 84–96; see also Krieger and Peters (2020), p. 363.

[295] ITLOS *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area* (Advisory Opinion), 1 February 2011, ITLOS Report 2011, 10, paras.132 & 135.

[296] Note, though, that some commentators have advanced the view that the precautionary principle/approach should be operationalized in a multi-faceted manner under which decisions on geoengineering testing and deployment must be taken on the basis of a balancing of the (environmental) risks involved. See Proelss (2017a), pp. 89–96; Proelss (2010), p. 81; Du (2019), pp. 202–213; Schröter (2015), pp. 293–320.

[297] Brent (2018), p. 161.

and practical rules for the attribution of liability.[298] It is, therefore, surprising that the issue of liability for damage caused by geoengineering research or deployment, unlike the question of the international legality of the activities concerned, has received little attention in legal scholarship to date.[299] Of the three recent legal monographs addressing geoengineering,[300] only one goes beyond superficially dealing with liability for environmental and other forms of harm.[301] Therefore, the following observations are intended to contribute to closing this gap in academic literature.

114 In accordance with what has been elaborated on in Chap. 3 of this book, it is necessary to differentiate between situations where a geoengineering activity violates international law and where this is not the case. As has been demonstrated above, while geoengineering as a scientific field is not generally prohibited under international law, individual field experiments and operational activities may well prove to be incompatible with the legal requirements arising from the relevant international agreements or customary international law. Furthermore, it is also crucial to distinguish instances where a geoengineering experiment or deployment is organised and conducted by a State from instances where the relevant activity is carried out by private actors. In addition to these distinctions, the degree of liability arising in a given case as a result of geoengineering activities will depend on the nature of the geoengineering project, the type and extent of damage that such project may allegedly cause and the laws applicable to a specific project.[302] The following Subchapters highlight the relationship between geoengineering activities and, on the one hand, State responsibility (¶ 115 *et seq*) and, on the other hand, State liability (¶ 126 *et seq*) with the latter discussion distinguishing between specialised and general liability regimes applicable to geoengineering. Subsequent to this discussion, Sect. 9.5.3 addresses the challenges in attributing liability and/or causation to a particular geoengineering activity before turning to an examination of operator liability for damage caused as a result of geoengineering activities (¶ 140 *et seq*).

9.5.1 State Responsibility

Attribution

115 Irrespective of a given scenario's details, if it involves a geoengineering activity that violates a rule or principle codified in an international treaty, or this is accepted

[298] Hester (2018), p. 224.

[299] The few exceptions include: Horton et al. (2015), Saxler et al. (2015), Brent (2018), Hester (2018) and Pfrommer et al. (2019).

[300] Krüger (2020), Du (2019) and Reynolds (2019b).

[301] Reynolds (2019b), pp. 178–195; Krüger (2020), pp. 114–119, only addresses liability for activities carried out in outer space.

[302] Hester (2018), p. 224.

as being valid under customary international law, the activity in question will entail the responsibility of the State if it is attributable to that State. The State concerned is then under an obligation to "make full reparation for the injury caused by the internationally wrongful act" and the scope of compensable damage is, as a matter of principle, directly related to the general rules of State responsibility.[303] Generally speaking, an action is attributable to a State if it has acted through one of its organs.[304] In contrast, private behaviour is usually not attributable to a State unless it involves situations where private actors, such as companies or private research institutes, have been empowered by domestic law to exercise governmental authority (see Article 5 ASR). However, even under these circumstances the law on State responsibility only recognises two situations where private conduct must be attributed to a State: First, according to Article 8 ASR, attribution can be established if the State has effectively controlled the activity concerned. Second, the private conduct is attributable to the State if the latter, either expressly or tacitly through its conduct, "acknowledges and adopts the conduct in question as its own" (Article 11 ASR).[305]

In the current context, it will normally not be possible to assume that either of these two situations exists. Having regard to the case law of the ICJ, the requirements to be met under the aforementioned provisions are very high. In particular, the granting of a permit to a private operator to carry out a certain geoengineering experiment or activity in the context of an authorisation procedure prescribed by law does not lead to that activity being attributable to the State. Indeed, the acts of a private actor cannot be deemed as sovereign acts unless the authorisation or approval concerned allocates the right to exercise elements of governmental authority to the private actor. **116**

While Article 11 ASR "provides for the attribution to a State of conduct that was not or may not have been attributable to it at the time of commission, but which is subsequently acknowledged and adopted by the State as its own",[306] it is not sufficient that the State only supports or endorses the activity.[307] Rather, Article 11 ASR "makes it clear that what is required is something more than a general acknowledgement of a factual situation, but rather that the State identifies the conduct in question and makes it its own".[308] **117**

[303] Article 31(1) ASR; see also ICJ *Corfu Channel Case* (United Kingdom v Albania) [1949] ICJ Rep 4, 23; ICJ *Gabçikovo-Nagymaros* (Hungary v Slovakia) [1997] ICJ Rep 7, para. 149.

[304] Article 4 ASR.

[305] ILC, Draft Articles on Responsibility of States for Internationally Wrongful Acts, with Commentaries, Yearbook of the ILC 2001-II/2, p. 54, Commentary to Article 11, para. 9.

[306] ILC, Draft Articles on Responsibility of States for Internationally Wrongful Acts, with Commentaries, Yearbook of the ILC 2001-II/2, p. 52, Commentary to Article 11, para. 1.

[307] ILC, Draft Articles on Responsibility of States for Internationally Wrongful Acts, with Commentaries, Yearbook of the ILC 2001-II/2, p. 53, Commentary to Article 11, para. 6.

[308] ILC, Draft Articles on Responsibility of States for Internationally Wrongful Acts, with Commentaries, Yearbook of the ILC 2001-II/2, p. 53, Commentary to Article 11, para. 6.

118 The situation could be assessed differently if a geoengineering experiment is carried out by a public research institute acting under the relevant national legislation. In such cases, the issue of attribution must arguably be addressed in the same way as cases involving State-owned enterprises (SOEs). However, the ILC commentaries on the ASR are of little help as far as acts of SOEs are concerned. In particular, the ILC considered the fact that while "an entity can be classified as public or private according to the criteria of a given legal system" this is *not* decisive for attribution under Article 5 ASR. From the ILC's perspective, the opposite is true as attribution under the rule codified in Article 5 ASR requires "that these entities are empowered, if only to a limited extent or in a specific context, to exercise specified elements of governmental authority".[309] Taking into account that governmental authority usually becomes manifest in the exercise of powers ('empowered') vis-à-vis private actors,[310] research activities that are undertaken to gain new scientific insight cannot be held to be of such nature. Thus, it must be concluded that even public research institutes should usually be considered as private actors.

Scope of Due Diligence Obligations of States

119 Situations where it is not possible to attribute private conduct to a State must be distinguished from cases where the State may have omitted to properly supervise private actors acting within its sphere of jurisdiction. In such cases, the question is whether the State has violated its own due diligence obligations arising from international law, namely whether a breach of a rule or principle of international law has occurred which gives rise to the international responsibility of the State concerned. In such cases, the relevant conduct of the State giving rise to its responsibility takes the form of an omission, typically regarding aspects of regulation, supervision, monitoring, enforcement and so forth. As far as the scope of due diligence is concerned, the ICJ famously held that:

> Due diligence entails not only the adoption of appropriate rules and measures, but also a certain level of vigilance in their enforcement and the exercise of administrative control applicable to public and private operators, such as the monitoring of activities undertaken by such operators.[311]

120 This is particularly relevant in the context of geoengineering activities since certain methods, especially those that may be relatively cheap and technically easy to deploy, may be conducted by private operators.[312] Taking into account that there is no uniform standard of due diligence that would apply independent of the

[309] All quotations from ILC, Draft Articles on Responsibility of States for Internationally Wrongful Acts, with Commentaries, Yearbook of the ILC 2001-II/2, p. 43, Commentary to Article 5, para. 3.

[310] See also ILC, Draft Articles on Responsibility of States for Internationally Wrongful Acts, with Commentaries, Yearbook of the ILC 2001-II/2, p. 43, Commentary to Article 5, para. 7: "The internal law in question must specifically authorize the conduct as involving the exercise of public authority; it is not enough that it permits activity as part of the general regulation of the affairs of the community".

[311] ICJ *Pulp Mills on the River Uruguay* (Argentina v Uruguay) [2010] ICJ Rep 14, para. 197.

[312] Hubert (2020), p. 51.

circumstances of the specific case,[313] it is not easy to identify general criteria for when a State has violated its due diligence obligations in a geoengineering context. That said, it must be borne in mind that as far as the realm of international environmental law is concerned, the obligation to exercise due diligence is conceptually related to the principle of prevention (¶ 106 *et seq*). A State is therefore obliged to take all possible and reasonable measures to avoid likely transboundary environmental damage. This has also been confirmed by the ILC in its Draft Articles on Prevention of Transboundary Harm from Hazardous Activities:

> The obligation of the State of origin to take preventive or minimization measures is one of due diligence. It is the conduct of the State of origin that will determine whether the State has complied with its obligation under the present articles. The duty of due diligence involved, however, is not intended to guarantee that significant harm be totally prevented, if it is not possible to do so. In that eventuality, the State of origin is required, as noted above, to exert its best possible efforts to minimize the risk. In this sense, it does not guarantee that the harm would not occur.[314]

If applied to the geoengineering context, these authoritative statements can only be understood in such a way that whenever the organs of a State have active knowledge of a geoengineering activity planned by private individuals or corporations which is likely to result in significant transboundary harm and yet fail to prevent the activity concerned, the State violates its due diligence obligation. This also applies when a State does not adequately monitor a geoengineering experiment that has been authorised by one of its agencies.[315] If a State, by way of regulation, creates incentives (presumed to be lawful) for private behaviour that could lead to transboundary environmental damage, it is obliged to take all possible steps to ensure that no damage occurs in accordance with its international obligations. It is not completely clear whether or not the same can be said in situations where a State makes no effort to regulate certain conduct that, if engaged in, is likely to cause environmental damage. On the one hand, a State cannot be expected, by reference to its duty of care, to regulate all conduct without there being real evidence that the conduct in question will result in environmental damage. Once such evidence exists, because a geoengineering experiment has been publicly announced or the competent authority becomes aware of it by other means, the State is obligated to take preventive action arising from its due diligence obligations. **121**

As far as the specific measures are concerned that must be taken in such a situation, the ICJ clarified in the *Pulp Mills Case* that "due diligence, and the duty **122**

[313] ITLOS *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area* (Advisory Opinion), 1 February 2011, ITLOS Report 2011, 10, para. 117.

[314] ILC, Draft Articles on on Prevention of Transboundary Harm from Hazardous Activities, Yearbook of the ILC 2001/II-2, p. 148, Commentary to Article 33, para. 7.

[315] See also ICJ *Pulp Mills on the River Uruguay* (Argentina v Uruguay) [2010] ICJ Rep 14, para. 197; ITLOS *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area* (Advisory Opinion), 1 February 2011, ITLOS Report 2011, 10, para. 138.

of vigilance and prevention which it implies, would not be considered to have been exercised" if an activity which may potentially affect the environment of another State or BBNJ is not subjected to an EIA on the potential effects of that activity before it is carried out (¶ 106 *et seq*). The standard of due diligence to be applied by a State may also be specified by reference to the relevant documents adopted by international actors such as the COPs/MOPs of the pertinent multilateral environmental agreements whose treaty mandates cover the potential negative effects of geoengineering.[316] In this respect, CBD Decision X/33 calls upon States parties to the CBD to ensure that no geoengineering activities take place "with the exception of small scale scientific research studies that would be conducted in a controlled setting [. . .], and only if they are justified by the need to gather specific scientific data and are subject to a thorough prior assessment of the potential impacts on the environment".[317] While this Decision is not legally binding *sensu stricto*, the ILC stated in the context of its work on subsequent agreements and subsequent practice in relation to the interpretation of treaties that "interpretative resolutions by Conferences of States Parties which are adopted by consensus, even if they are not binding as such, can nevertheless be subsequent agreements under article 31, paragraph 3 (a), or subsequent practice under article 31, paragraph 3 (b) [VCLT]".[318] Consequently, there is good case to argue that the requirements contained in this Decision, which was adopted by consensus, can be relied upon when assessing whether or not a State has acted in line with its due diligence obligation to prevent significant transboundary harm. Similarly, States parties to the London Protocol are arguably not free to disregard the resolutions that have been adopted by the MOP vis-à-vis geoengineering (¶ 93 *et seq*) and future developments in relevant fora will further impact what can be expected from States when analysing whether they have observed the pertinent standard of due diligence. In view of the foregoing, it must be kept in mind that "[t]he standard of due diligence has to be more severe for the riskier activities".[319] Thus, in light of the environmental and other risks involved, the distinction between testing and deployment of geoengineering cannot as easily be drawn as with other cutting-edge technologies such as seabed mining (Chap. 13). As such, the due diligence standard to be applied in the geoengineering context may indeed need to be stricter and less flexible than with regard to other activities.

Causal Relationship

123 Aside from the issue of attribution in terms of the law on State responsibility, proof of the factual basis of a causal relationship between a geoengineering activity

[316] See also Boyle and Redgwell (2021), pp. 165–166; Dupuy and Viñuales (2015), p. 313.

[317] CBD X/33, para. 8(w).

[318] UN Doc A/69/10, Report of the International Law Commission on the Work of its Sixty-Sixth Session (2014), Chapter VII, Commentary to Draft Conclusion 10, p. 76, para. 38. Note that the ILC made specific reference to resolutions adopted by the parties to the London Convention and protocol vis-à-vis geoengineering; ibid., para. 12.

[319] ITLOS *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area* (Advisory Opinion), 1 February 2011, ITLOS Report 2011, 10, para. 117.

and harm that has occurred afterwards may be particularly difficult given the complexity of climatic systems and the multitude of human stressors currently affecting the environment. For example, one of the environmental risks associated with ice restoration (¶ 25 *et seq*) is ocean acidification but 'attributing', in the sense of establishing a causal nexus, an increase in ocean acidity with ice restoration activities will be difficult since ocean acidification also has multiple sources, including the high levels of atmospheric CO_2 caused by other human activities.[320] As has been alluded to earlier, if a geoengineering activity to restore ice is undertaken by private actors, the fact that a State has authorised such activity does not necessarily mean that any negative consequences of such an activity can be attributed to that State. While the existence of damage is usually *not* a precondition for responsibility under the law of State responsibility, a causal nexus is required when determining the compensation owed by a State due to its violation of international law. This issue will be discussed in more detail in Sect. 9.5.3 below (¶ 140 *et seq*).

Circumstances Precluding Wrongfulness

Finally, even if it is possible in individual cases to establish attribution in connection with geoengineering within the meaning of Articles 4–11 of the ASR and there have been violations of a rule or principle of international law, not all such unlawful acts will necessarily lead to the responsibility of the State. In this regard, the ASR list six circumstances that preclude the wrongfulness of conduct that would otherwise be a breach of the accepted primary obligations of the State concerned. In the context of geoengineering, two of these circumstances require brief mention.[321] First, Article 25 ASR provides that a State may rely on necessity as a defence for its conduct if it "is the only way for the State to safeguard an essential interest against a grave and imminent peril" and such conduct "does not seriously impair an essential interest of the State or States towards which the obligation exists, or of the international community as a whole". In the words of the ILC, necessity "arises where there is an irreconcilable conflict between an essential interest on the one hand and an obligation of the State invoking necessity on the other".[322] Extrapolated to geoengineering, there is perhaps some scope that a State may invoke necessity to safeguard an essential interest, such as reducing the impact of climate change, which is irreconcilable with a State's international obligations not to cause significant environmental harm. However, the State in question can only invoke the defence of necessity if it did not itself *contribute* to the situation of necessity.[323] If the ultimate aim is to reduce the impacts of anthropogenic climate change, it seems doubtful that any State will be successful in arguing that it has not contributed to climate change and is therefore entitled to invoke the defence of necessity.[324] That **124**

320 Brent et al. (2019), p. 40.

321 For an in-depth discussion see Krüger (2020), pp. 55–60.

322 ILC, Draft Articles on Responsibility of States for Internationally Wrongful Acts, with Commentaries, Yearbook of the ILC 2001-II/2, p. 80, Commentary to Article 25, para. 2.

323 Article 25(2)(b) ASR.

324 Reichwein et al. (2015), p. 174.

said, there arguably remains some restricted scope for a particularly vulnerable State to present creative legal arguments using their limited contribution to climate change and their necessity in developing or deploying a specific geoengineering method.

125 Second, Article 20 ASR provides that consent given by a State "to the commission of a given act by another State precludes the wrongfulness of that act in relation to the former State to the extent that the act remains within the limits of that consent". A full discussion of consent as a basis for precluding wrongfulness is beyond the scope of this study,[325] however, whether or not a State has validly given consent is generally accepted as being a "matter addressed by international law rules outside the framework of State responsibility".[326] In order to rely on consent as a basis for precluding wrongfulness, the consent must be given freely and the responsible State must operate within the ambit of such consent.[327] In the context of geoengineering, contributing to the adoption of either binding/non-binding decisions or recommendations within existing legal frameworks, including the UNFCCC and the London Convention/Protocol, may serve as proof of a particular State's consent.[328] If, for example, the COP of the UNFCCC adopts a decision calling on States to make use of certain CDR methods to reduce global CO_2 concentrations, States which demonstrate a certain amount of political will by supporting such an adoption may be seen as consenting to the adoption of these CDR methods. While the circumstances surrounding such consent will have to be evaluated on a case-by-case basis, it is plausible that one State which suffers damage as a result of another State's geoengineering activity may be precluded from holding the latter State internationally responsible because the injured State previously gave its consent. This is not to say that a State is exempt from any particular primary obligation, such as preventing harm to the environment, rather, "the primary obligation continues to govern the relations between the two States, but it is displaced on the particular occasion or for the purposes of the particular conduct by reason of the consent given".[329]

[325] For a comprehensive study of consent in the context of State responsibility see Abass (2004), pp. 211–225.

[326] ILC, Draft Articles on Responsibility of States for Internationally Wrongful Acts, with Commentaries, Yearbook of the ILC 2001-II/2, p. 73, Commentary to Article 20, para. 4.

[327] Abass (2004), p. 214.

[328] Although within the context of customary international law, while not viewing consent as a preclusion for wrongfulness, the ICJ held that the "effect of consent to the text of [. . .] resolutions cannot be understood as merely that of a 'reiteration or elucidation' of [a] treaty commitment [. . .]. On the contrary, it may be understood as an acceptance of the validity of the rule or set of rules declared by the resolution by themselves" (ICJ *Military and Paramilitary Activities in and against Nicaragua* (Nicaragua v United States of America) [1986] ICJ Rep 14, para. 188).

[329] ILC, Draft Articles on Responsibility of States for Internationally Wrongful Acts, with Commentaries, Yearbook of the ILC 2001-II/2, p. 73, Commentary to Article 20, para. 4.

9.5.2 State Liability

As far as State liability beyond State responsibility is concerned, it is first necessary to analyse whether specific liability regimes applicable to individual geoengineering activities exist before considering whether general international law provides for relevant rules and principles that could be applied in view of the specific nature and potential consequences of geoengineering. **126**

Liability Regimes Specifically Applicable to Geoengineering

Geoengineering activities that are conducted in outer space, which would apply to the deployment of installations or structures such as mirrors, may be covered by the terms of the Convention on International Liability for Damage Caused by Space Objects ("Liability Convention"). As is analysed in Annex B of this book, the Liability Convention is the only existing international agreement that comprehensively provides for State liability and the liability of international organizations for space-based activities. According to the definition of 'space object' enshrined in Article I(d) of the Convention, even components that were a part of a larger object can be classed as space objects and are covered by its terms. Taking into account that the term 'space object' must be understood as including any object that is launched into outer space, whatever its purpose, any geoengineering installations or structure deployed in outer space must be held to fall within the scope of the Convention. Also, with a view to geoengineering activities, the "mixed", or "dual" liability standard on which the agreement is based is of particular interest.[330] Article II imposes absolute State liability on the launching State for damage caused on the Earth's surface as well as to aircraft in flight. In contrast, Article III establishes fault-based liability which applies to damage inflicted on space objects belonging to other launching States which are not located on the Earth's surface. According to Article I (a), the Convention only covers damage to persons and property, not damage to the environment. As far as geoengineering activities in outer space are concerned, this is particularly problematic, since the introduction of installations or structures in space could affect global climate in a manner that negatively impacts parts of the environment on Earth. This problem could potentially be tackled by way of interpreting the term 'damage' in such a way that it also includes environmental harm that specifically affects the territory of a contracting State, and thus the 'property' of that State. In this sense, Canada substantiated its claim for compensation for the damage caused by the crash of the Soviet satellite Cosmos 954,[331] however, the fact remains that the Convention has so far not played any prominent role in State practice. This demonstrates that States will remain reluctant to accede to a treaty that provides for strict **127**

[330] For assessment see Horton et al. (2015), pp. 245–250.

[331] See Claim Against the Union of Soviet Socialist Republics for Damage Caused by Soviet Cosmos 954, ILM 18 (1979), p. 899 (905, para. 15); see also Frantzen (1991), p. 619 (with note 127); Gehring and Jachtenfuchs (1988), p. 107.

State liability, a fact that undermines the potential for success of any attempts to make the Liability Convention applicable to geoengineering activities.

128 With respect to the other geoengineering activities relevant here, no specific applicable liability regime is in place. As regards the sub-seabed storage of CO_2, the only existing liability regime that could potentially be applicable is enshrined in Part XI UNCLOS and its substantiating instruments (Chap. 13). However, as has been demonstrated above, the pertinent provisions only apply to "activities in the Area", which is defined in Article 1(1)(3) UNCLOS as "all activities of exploration for, and exploitation of, the resources of the Area". The SDC held in its 2011 advisory opinion that such activities need to be directly related to the recovery of minerals from the seabed and their lifting to the water's surface.[332] This would include, as enumerated in Article 145(a) UNCLOS, "drilling, dredging, excavation, disposal of waste, construction and operation or maintenance of installations, pipelines and other devices related to such activities",[333] although arguably not the sequestration of CO_2 into sub-seabed geological structures which were previously used for purposes related to the exploitation of mineral resources in the Area. In contrast to the disposal of water and materials of no commercial interest that are separated from deep seabed resources during the process of resource exploitation,[334] the activity relevant here constitutes a *separate* activity not *directly* linked to the exploitation of the deep seabed resources.[335] As can be demonstrated by reference to the different purposes, sequestration of CO_2 under the seabed would only take place during or following mineral-exploitation activities in the area.

129 Furthermore, neither the 1972 London Convention nor the 1996 Protocol, which specifically apply to both CO_2 sequestration and, subject to the entry into force of the 2013 amendment on marine geoengineering, to ocean iron fertilisation (¶ 92 *et seq*), contain stipulations on State liability. While both the Convention (Article X) and the Protocol (Article 15) require that the Contracting parties "undertake to develop procedures for the assessment of liability", they have so far refrained from implementing this regulatory mandate.[336]

130 Concerning marine geoengineering experiments, it is worth mentioning that Part XIII of the UNCLOS on marine scientific research (¶ 86 *et seq*) contains a provision

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[332] ITLOS *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area* (Advisory Opinion), 1 February 2011, ITLOS Report 2011, 10, para. 94.

[333] ITLOS *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area* (Advisory Opinion), 1 February 2011, ITLOS Report 2011, 10, para. 85.

[334] ITLOS *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area* (Advisory Opinion), 1 February 2011, ITLOS Report 2011, 10, paras. 95 & 97.

[335] See also Proelss and Güssow (2011), p. 156, arguing that marine CCS activities conducted in areas beyond the limits of national jurisdiction are covered by the principle of freedom of the high seas in terms of Article 87(1) UNCLOS and not by the regime of the Area.

[336] The 2012 Specific Guidelines for the Assessment of Carbon Dioxide for Disposal into Sub-seabed Geological Formations of 2 November 2012 (IMO Doc. LC 34/15, Annex 8) are also silent on the issue.

that is specifically dedicated to responsibility and liability. In particular, Article 263(3) UNCLOS stipulates that "States and competent international organizations shall be responsible and liable pursuant to article 235 for damage caused by pollution of the marine environment arising out of marine scientific research undertaken by them or on their behalf". This provision, as well as the other paragraphs of Article 263 UNCLOS, must be read in conjunction with Article 304 UNCLOS that states the "provisions of this Convention regarding responsibility and liability for damage are without prejudice to the application of existing rules and the development of further rules regarding responsibility and liability". Thus, while any new developments to the law on State responsibility are automatically applicable to both the law of the sea in general and Article 263 UNCLOS in particular,[337] the latter provision cannot be interpreted as establishing an autonomous regime of responsibility and liability with regard to activities that qualify as marine scientific research under the UNCLOS.[338] Even though the regime of Part XIII UNCLOS is based on the assumption that every private research project is automatically transformed into a research project of the applying State due to its involvement in the consent application procedure for conducting marine scientific research,[339] the rules of attribution, in particular, the principle of effective control embodied in Article 8 ASR, are not superseded by Article 263(1) UNCLOS.[340] Taking the opposite view would confuse both issues of attribution and of due diligence responsibility which, in turn, ignores the clear distinction between these two categories that is generally accepted in international practice and legal doctrine.[341] The ICJ clarified in the *Srebrenica Case* that responsibility based on attribution on the one hand and responsibility due to a violation of a due diligence provision on the other must be distinguished and are mutually exclusive.[342] Consequently, a State can only be held responsible for infringements of the UNCLOS caused by private actors, such as research entities, if the activity in question is attributable to the State in line with what has been analysed above. Additionally, while Article 263(1) UNCLOS creates "an indirect duty to monitor the activities of actors whose conduct would not be attributable to States and international organizations under the regular rules of attribution",[343] the 'researching State' can only be held responsible to the extent that it has violated its due diligence duty to monitor the relevant private actor's conduct.[344]

[337] Hofmann and Proelss (2015), p. 182.

[338] See also Stephens (2017), paras. 7, p. 23; Tams and Devaney (2017), paras. 17–19.

[339] For reasoning and further references see Hofmann and Proelss (2015), p. 174.

[340] *Contra* Wegelein (2005), p. 350.

[341] Hofmann and Proelss (2015), p. 183.

[342] ICJ *Application of the Convention on Prevention and Punishment of the Crime of Genocide* (Bosnia and Herzegovina v Serbia and Montenegro) [2007] ICJ Rep 43, para. 382.

[343] Tams and Devaney (2017), para. 12.

[344] See ITLOS *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area* (Advisory Opinion), 1 February 2011, ITLOS Report 2011, 10, para. 109: "not every violation of an obligation by a sponsored contractor automatically gives

131 As far as the introduction of substances with high albedo into the atmosphere is concerned, no special regime is in place which would govern State liability for damage that has arisen in the context of activities that take place or which produce effects in the atmosphere. As previously mentioned, there is still uncertainty with regard to the exact location of the border between air space, which is subject to State sovereignty, and outer space, which has become to be accepted as a common space by virtue of the Outer Space Treaty. However, it is generally accepted that the atmosphere ends at an altitude of somewhere between 80 and 120 km, [345] meaning the geoengineering methods discussed here are not covered by the Liability Convention mentioned above. In contrast, the 1979 Convention on Long-Range Transboundary Air Pollution (CLRTAP), which is potentially applicable to the geoengineering methods relevant here (see Sect. 9.4.1, § 102), expressly clarifies in a footnote to Article 8 that it "does not contain a rule on State liability as to damage".

132 Finally, brief mention should be made of State liability regimes applicable in the polar regions as such liability regimes would be particularly relevant in the context of geoengineering methods associated with the restoration of sea ice. While no specific liability regime exists for the Arctic, the Antarctic Liability Annex (Chap. 12) applies to "environmental emergencies in the Antarctic Treaty area which relate to scientific research programmes, tourism and all other governmental and non-governmental activities". An 'environmental emergency' is defined as "any accidental event that [. . .] results in, or imminently threatens to result in, any significant and harmful impact on the Antarctic environment". Following this, it is clear that the deliberate act of restoring sea ice would not be covered by the Antarctic Liability Annex. Additionally, the Antarctic Liability Annex is yet to enter into force and the strict liability standard set by the Annex suggests that it faces the same hurdle as the Space Liability Convention, namely that States remain reluctant to ratify international agreements that provide for strict liability.

Are General Liability Rules Applicable to Geoengineering?

133 Notwithstanding the lack of liability regimes specifically applicable to geoengineering, one may ask whether States can still be held liable for any damage in light of the serious environmental, political and social risks involved in the activities concerned (¶ 49 *et seq*). This would require that the standard of strict State liability be generally accepted for such situations. *Prima facie*, the concept of 'ultra-hazardous activities' could potentially be referred to as a legal basis for this liability standard.

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rise to the liability of the sponsoring State. Such liability is limited to the State's failure to meet its obligation to "ensure" compliance by the sponsored contractor".

[345] Arguably, the fact that "complete and exclusive sovereignty over the airspace" allocated to each State by Article 1 of the Chicago Convention on International Civil Aviation of 7 December 1944 (15 UNTS 295) can only be exercised where aircraft traffic is technically possible, militates in favour of accepting that the delimitation of air space and outer space should be based on the flight dynamic criteria reflected in the "Kármán line" located at an altitude of 83,6 km. See Proelss (2017b), pp. 369–371.

In its Draft Articles on the Prevention of Transboundary Harm from Hazardous Activities,[346] the ILC regarded as 'ultra-hazardous' any activities that are characterised by "a danger that is rarely expected to materialize but might assume, on that rare occasion, grave (more than significant, serious or substantial) proportions".[347] Relevant factors to determine whether the consequences of a certain activity are to be considered as 'grave' include the number of injured persons, the scale of damage to property and the like, the significance of environmental impacts as well as the duration and territorial extent of the damage.[348] Examples of relatively commonplace activities where such criteria could apply are the peaceful use of nuclear energy, the bulk transport of oil and the handling of hazardous wastes.[349] **134**

Current assumptions concerning the potential negative side effects of, say, the introduction of light-reflecting substances into the atmosphere illustrate that large-scale field tests and deployment of this geoengineering method could potentially lead to disastrous consequences for humankind, the climate and ecosystems (¶ 52 *et seq*, 60 *et seq*). Given that even activities with a low probability of causing 'grave' damage can be considered as 'ultra-hazardous', this must *a fortiori* be the case for activities where the probability to cause damage may not easily be determined but if it does occur, has the potential to be catastrophic. It has thus been argued that activities with significant uncertainty regarding the likely occurrence of catastrophic harm should be classed as having a higher level of 'ultra-hazardousness' than activities with a definably low probability of doing so.[350] Against this background, there is good case to argue that some SRM geoengineering techniques must be categorised as 'ultra-hazardous'. **135**

However, even with regard to 'ultra-hazardous' activities, State practice does not yet seem to sufficiently support the existence of strict State liability for otherwise lawful acts.[351] With the single exception of the space liability regime (¶ 100 *et seq*), the pertinent international agreements establish civil liability of the operator, ship-owner and so forth but not, at least not specifically, State liability.[352] The extent to which, or even if, these agreements provide for residual State liability, cannot be held to reflect a general rule of customary international law (Chap. 3 ¶ 14 *et seq* (Sect. 3.3.2)). As stated by the SDC of the ITLOS, "[a] gap in liability which might occur in **136**

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[346] ILC, Draft Articles on Prevention of Transboundary Harm, Yearbook of the ILC 2001-II/2, p. 148. Article 1 clarifies that the Draft Articles "apply to activities not prohibited by international law which involve a risk of causing significant transboundary harm through their physical consequences".

[347] ILC, Draft Articles on Prevention of Transboundary Harm, Yearbook of the ILC 2001-II/2, p. 149, Commentary to Article 1, para. 2. See also Jenks (1966), p. 107.

[348] Dederer (2013), p. 16 (note 5).

[349] Dederer (2013), p. 16.

[350] Saxler et al. (2015), pp. 125–126.

[351] Saxler et al. (2015), pp. 126–128, referring to Montjoie (2010), p. 507 and Boyle and Redgwell (2021), p. 228.

[352] Beyerlin and Marauhn (2010), p. 367; additional arguments against the existence of a customary legal regime of strict State liability are discussed by Montjoie (2010), pp. 507 *et seq*.

such a situation cannot be closed by having recourse to liability of the sponsoring State under customary international law. The Chamber is aware of the efforts made by the International Law Commission to address the issue of damages resulting from acts not prohibited under international law. However, such efforts have not yet resulted in provisions entailing State liability for lawful acts".[353] Similarly, State liability for damage arising from 'ultra-hazardous' activities can also not be regarded as a general principle of law in terms of Article 38(1)(c) of the ICJ Statute. While strict standards of liability for particularly dangerous activities have indeed come to be accepted in several domestic legal systems, as well as international agreements addressing civil liability,[354] these instruments are not based on a sufficiently uniform approach so as to regard them as generally accepted.[355]

Challenges in "Attributing" Responsibility/Liability for Geoengineering Activities

137 A precursor to establishing the responsibility or liability of a State for damage which has arisen in the context of a geoengineering activity is resolving the crucial issues of the existence of a causal nexus between damage that has occurred and a certain activity, be it unlawful or lawful. Within the realm of 'attribution science', this nexus has come to simply be described by the term attribution,[356] however, reference to the term 'causation' is arguably preferable to avoid the issue concerned being confused with attribution in the sense of the law of State responsibility. While the deployment of a particular geoengineering method will usually be relatively easy to allocate to a particular actor, whether that particular deployment is the cause of damage that has occurred would be challenging to prove, especially if the damage occurred on the opposite side of the globe and at a much later date. Nevertheless, making such an attribution will be necessary for the purposes of determining compensation.[357] In other words, plaintiffs may face difficult challenges in proving that the deployment of a specific method was the cause of the damage rather than a

[353] ITLOS *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area* (Advisory Opinion), 1 February 2011, ITLOS Report 2011, 10, para. 168. By guaranteeing that victims of damage are compensated in cases where the operator cannot provide full compensation, residual State liability could still play a supplementary role with regard to future geoengineering liability regimes. It should be remembered that States are of course still required to fulfil their own due diligence obligations where the standard, according to the SDC of ITLOS, "has to be more severe for the riskier activities" and which require sponsoring States to adopt "'laws and regulations' and to take 'administrative measures which are, within the framework of its legal system, reasonably appropriate for securing compliance by persons under its jurisdiction'" (ITLOS *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area* (Advisory Opinion), 1 February 2011, ITLOS Report 2011, 10, paras. 117–119).

[354] For references see Saxler et al. (2015), p. 127.

[355] See COM(93)47 of 14 May 1993, Green Paper on Remedying Environmental Damage, para. 2.2.1. For further references see Boyle and Redgwell (2021), pp. 228–230.

[356] See for example, the National Academies of Sciences, Engineering, and Medicine (2016).

[357] Svoboda and Irvine (2014), p. 158; Hester (2018), p. 246; Lin (2013b), p. 140.

natural climate phenomenon or some other human activity. As described above (Chap. 3 ¶ 64 *et seq* (Sect. 3.4.4)), the issue relevant here was briefly addressed by the ICJ in the *Wetland Compensation Case*,[358] although the Court refrained from providing any general guidelines that could be used for 'attribution' of harm in geoengineering cases due to the specificities of that case.

Establishing a causal link between an activity and damage in the context of responsibility and liability has two legal dimensions: First, violations of multinational environmental agreements can sometimes only be determined if a causal relationship exists between pollution and harm. For example, the CLRTAP obliges its States parties to limit, reduce and prevent air pollution as far as possible.[359] According to the definition of the term 'air pollution' in Article 1(a), the introduction of substances has to result "in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems and material property and impair or interfere with amenities and other legitimate uses of the environment". It is thus necessary that a causal link exists between the introduction of substances on the one hand and deleterious effects on the other to assume pollution has occurred.[360] Secondly, as can be demonstrated by reference to the *Wetland Compensation Case*, and notwithstanding the fact that the existence of damage is usually *not* a precondition for responsibility under the law of State responsibility, a causal nexus is required when determining the compensation owed by a State due to a violation of international law attributable to it. In the words of the ICJ: **138**

> In order to award compensation, the Court will ascertain whether, and to what extent, each of the various heads of damage claimed by the Applicant can be established and whether they are the consequence of wrongful conduct by the Respondent, by determining 'whether there is a sufficiently direct and certain causal nexus between the wrongful act [. . .] and the injury suffered by the Applicant.[361]

The difficulty in proving a causal nexus between a particular activity and damage is compounded by the fact that no universally valid standard of proof exists in international law.[362] Accepted categories include 'proof beyond a reasonable doubt',[363] '(clear and) convincing evidence',[364] 'conclusive evidence'[365] and **139**

[358] ICJ *Certain Activities Carried Out by Nicaragua in the Border Area* (Costa Rica v Nicaragua) [2018] ICJ Rep 15, para. 34.

[359] See CLRTAP Article 2.

[360] Rickels et al. (2011), p. 90; see also Bodle et al. (2014), pp. 61–63; Saxler et al. (2015), p. 120.

[361] ICJ *Certain Activities Carried Out by Nicaragua in the Border Area* (Costa Rica v Nicaragua) [2018] ICJ Rep 15, para. 32.

[362] Saxler et al. (2015), p. 120.

[363] Rome Statute of the International Criminal Court, 17 July 1998, 2187 UNTS 3, Article 66(3); see also ICTY *Prosecutor v Tadic* (Final Judgment) (Appeals Chamber) IT-94-1-A, 15 July 1999, para. 233.

[364] *Trail Smelter Case* (United States v Canada) (1941) 3 RIAA 1905, 1965.

[365] ICJ *Pulp Mills on the River Uruguay* (Argentina v Uruguay) [2010] ICJ Rep 14, para. 265.

'preponderance of evidence'[366] However, even the lowest of these standards ('preponderance of evidence') relies on probabilities and uses a 'more likely than not' threshold.[367] In assessing whether particular damage could be caused by a particular geoengineering activity, there is currently no option other than relying on the projections of climate models where their reliability is subject to intense debate. For the time being, it remains unclear whether the 'preponderance of evidence' standard can be used in a way to provide satisfactory proof of a causal link between the damage and certain geoengineering activities for the actors that would be involved. At the same time, the discussion held in Chap. 8 shows that much is in flux here. It has recently been proposed to apply the Fraction of Attributable Risk (FAR) to geoengineering,[368] a methodological approach currently used to tackle the problem of causation in climate litigation.[369] The reasoning here is that it is possible to operationalise FAR estimates to provide evidence in the context of inter-State court trials by recourse to a slightly modified version of a set of criteria governing the admissibility of evidence, a process which has become accepted in the US legal system in the shape of the Daubert standard.[370] According to this standard, which was applied by the US Supreme Court in *Daubert v Merrell Dow Pharmaceuticals*, a seemingly new scientific methodology is valid and can thus potentially serve as admissible evidence before a court if: (i) the theory or technique in question can be and has been tested; (ii) it has been subjected to peer review and publication; (iii) its known or potential error rate is considered; (iv) standards controlling its operation exist and are maintained; and (v) it has attracted widespread acceptance within the relevant scientific community.[371] The details of this standard which, if slightly modified would allow for an assessment of climate models,[372] cannot be discussed in detail here. However, the approaches that have been applied in international case law to date, in particular, the 'preponderance of evidence' standard,[373] seem to be flexible enough to make recourse to the Daubert or other potentially relevant criteria possible.[374] This view also appears to be justifiable given the lack of both a sophisticated theory of causality and evidence requirements that could be applied

[366] ICJ *Case concerning the Land, Island and Maritime Frontier Dispute* (El Salvador v Honduras; Nicaragua intervening) [1992] ICJ Rep 351, para. 248. On the variety of the standards of proof referred to by the ICJ see Benzing (2019), p. 1234, para. 108; Del Mar (2012), p. 99.

[367] This threshold has been applied by domestic courts in the UK and US; for references see Saxler et al. (2015), p. 121.

[368] Horton et al. (2015), pp. 261–264.

[369] Allen (2003), p. 891; Allen et al. (2007), pp. 1353–1400.

[370] Pfrommer et al. (2019), pp. 67–84.

[371] US Supreme Court *Daubert v Merrell Dow Pharmaceuticals* (1993) 509 U.S. 579, pp. 593–594.

[372] Pfrommer et al. (2019), pp. 75–80.

[373] See also Frank (2014), p. 6, claiming that "preponderance of evidence" should be used as the standard of proof in the context of determining causality between greenhouse gas emissions and environmental damage.

[374] See Tomka and Proulx (2015), stating that "the Court does not operate on the basis of any preliminary evidentiary filter to weed out inadmissible evidence at the outset; rather, the Court

in proceedings at the international level.[375] All this leads to the conclusion that the challenges in ‘attributing’ responsibility/liability for geoengineering activities can indeed be overcome.

9.5.3 Operator Liability

140 Some of the existing civil liability regimes which address different kinds of transboundary hazardous activities may be applicable to accidents arising from, or in the context of, geoengineering activities. For example, in a scenario where a shipping accident occurs on the high seas in connection with the transfer of liquid CO_2 to a sequestration facility, operator liability could arise, subject to its entry into force under the 1999 Basel Protocol on Liability and Compensation for Damage Resulting from Transboundary Movements of Hazardous Wastes and their Disposal. Article 3(3)(c) of this Protocol clarifies that it is also applicable to certain damage that occurs in areas beyond national jurisdiction, such as the high seas. However, this only applies to ‘traditional’ forms of damage, namely loss of human life, personal injury and property as well as the costs of taking preventive measures. In contrast, the costs for taking the necessary measures to restore the impacted environment in such areas are not included, probably because it is unclear how such restoration could be carried out on the high seas. As demonstrated above, the Basel Protocol establishes a standard of strict liability for actors subject to the jurisdiction of either the State of export or the State of import and who act as a notifier, exporter, importer or disposer of the wastes concerned. In contrast, the ‘carrier’, that is any person who merely carries out the transport of hazardous wastes or other wastes, is only subjected to fault-based liability (Chap. 15 ¶ 17 (Sect. 15.2.3)). This standard would thus usually apply in the conceivable scenarios relevant in a geoengineering context.

141 In contrast, the International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea (HNS Convention),[376] which has similarly not yet entered into force, would not be applicable to maritime accidents involving the discharge of liquefied CO_2. While the Convention establishes the liability of the shipowner under its Article 7 and, per se, covers damage caused in the EEZs of any of the States parties[377] and to

possesses a wide margin of appreciation in ascribing different weight to different evidentiary elements originating from varied sources” (11).

375 Tomka and Proulx (2015), p. 3: “the rigidity of evidentiary rules found in some municipal legal systems has not been transposed integrally to the international legal order. Quite the contrary, the rule of thumb for evidentiary matters before the Court is flexibility”.

376 Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea, 3 May 1996, available at: https://www.hnsconvention.org/wp-content/uploads/2018/08/2010-HNS-Convention-Consolidated-text_e.pdf (accessed on $).

377 See Article 3(b) HNS Convention.

the high seas as far as any damage other than the contamination of the environment is concerned.[378] However, liquefied CO_2 is not a substance that must be treated as hazardous or noxious under the Convention. Article 1(5) of the Convention defines hazardous and noxious substances by reference to other IMO Conventions and Codes and, as far as can be seen, liquefied CO_2 is not included in any of these documents. Furthermore, it is not mentioned in Chapter 17 of the International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk (IBC Code),[379] which is referred to by the HNS Convention with respect to dangerous liquid substances, nor is it listed in Chapter 19 of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code),[380] which is the relevant document under the HNS Convention concerning liquefied gases.

142 With the exception of the aforementioned treaties, no specific operator liability regime can be envisaged to be applicable to the mitigation of geoengineering-related damage, no matter which damage scenario is involved. As has been demonstrated in Chap. 4 (Chap. 4 ¶ 7 *et seq* (Sect. 4.2.1)), general international law does not yet accept the concept of direct international liability of private actors, even though the legal situation in this regard is, arguably, evolving. This assessment also applies to geoengineering activities conducted by entities such as private research institutes. Thus, if a geoengineering experiment undertaken and controlled by private actors results in environmental damage, provided that the institution's home State has complied with its due diligence obligation to avoid falling foul of State responsibility, no legal basis for a liability claim exists. While such a legal basis could be created by concluding an international treaty establishing the strict direct liability of private actors, no such agreements have yet come into existence in the context of geoengineering. That said, in line with what has been analysed in Chap. 8 in relation to climate litigation, it is still possible that companies or institutions causing damage may be held liable under the domestic law of their home States via tort litigation even if the damage has occurred in another part of the world.

9.6 The Way Forward: State Responsibility and Liability for Geoengineering Damage

143 Against the background of the analysis undertaken in the preceding Subchapters, this Subchapter discusses potential future developments concerning the development of a liability regime for geoengineering. The development of a suitable liability regime

[378] But only if damage has been caused by a substance carried on board a ship registered in a State party or, in the case of an unregistered ship, on board a ship entitled to fly the flag of a State party. See Article 3(c) HNS Convention.

[379] IMO Resolution MSC.4(48) of 17 June 1983.

[380] IMO Resolution MSC.5(48) of 17 June 1983.

for geoengineering faces numerous challenges. Besides the problem of establishing a causal relationship between a geoengineering activity on the one hand and damage which has occurred on the other, a problem which does appear to be solvable (¶ 123), these challenges can be summarised into the following six points:

First, what is the 'climate baseline' against which damage, potentially caused by geoengineering, is to be evaluated?[381] When assessing the harm, it will be necessary to establish a baseline from which to measure the damage. Should the baseline be the preindustrial climate change environment, the climate immediately prior to the deployment of the specific geoengineering method or the climate that would likely exist should the activity in question not have been conducted? **144**

Second, the attribution of responsibility and liability presents societal issues. For example, a State that benefits from or simply prefers a warmer climate may choose to claim for harm suffered by the cooling effects of SRM methods. Alternatively, requiring a developing State with historically low emissions that nevertheless engages in CDR activities to safeguard its own climate change interests to pay compensation to a traditionally high-emitting industrialised State that suffers harm seems incompatible with theories of social justice and fairness. **145**

Third, outcomes that damage one actor may be beneficial to other third actors, creating one victim but several beneficiaries. Would such third-party beneficiaries be required to assist in paying compensation in the absence of an international fund or in the event that the actor deploying the particular geoengineering method is unable to pay the damages awarded? Fourth, disagreement concerning why victims should be compensated has the potential to impact policy-making. In this regard, approaches that "are based on ex post corrective justice, for example, would differ substantially from those based on altering actors' ex ante incentives to encourage socially optimal outcomes".[382] Fifth, States are generally reluctant to pay compensation and even less willing to acknowledge international legal liability. Lastly, compensation is almost always provided by means of a monetary remedy. In line with current environmental agreements, State liability for a particular geoengineering activity would typically only result in monetary damages to be paid and, unless the regime of State responsibility applies, would not allow a claimant State to prevent or stop the damaging geoengineering activities of another State.[383] All this has prompted one commentator to take a particularly sobering view concerning the development of a suitable liability regime: **146**

> As a result, any liability regime is unlikely to make whole those nations and individuals harmed by geoengineering. For many of the same reasons, an environmental assurance bond requirement similar to that proposed for nanotechnology would not be a suitable primary mechanism for governing geoengineering. The potential harms are simply too irreversible, irremediable, and catastrophic for monetary damages to suffice. Just as common law tort provides for injunctive relief in situations where damages are inadequate, the difficulty of

[381] Lin (2013b), p. 140.

[382] Reynolds (2019a).

[383] See Lin (2013b), p. 140, holding that "[m]onetary damages are likely to be a poor remedy for many of the harms that result from geoengineering".

> establishing, measuring, and making up for adverse consequences calls for a cautious approach to geoengineering.[384]

147 Other commentators disagree with this position, arguing that "[h]istorical antecedents and contemporary methodological and legal innovations provide a strong basis for constructing a liability regime".[385] Indeed, while there cannot be any doubt that the call for a cautious approach to geoengineering deserves approval in light of the risks involved in virtually any of the geoengineering approaches discussed above (¶ 49 *et seq*), this should not be used as an argument to refrain from efforts to develop an appropriate liability regime. Quite the opposite, it is crucially important that a liability system be modelled in such a way that it provides the right incentives for any actors deciding to carry out geoengineering so the methods used are deployed in a way that ensures the greatest possible protection of other goods and values, including the environment and climate. At the same time, a liability system established at the *international* level requires States to be willing to agree to it and, if the liability risk is too high, no matter for which actor, States may decide to boycott the underlying regime, a possibility that militates in favour of a flexible approach.[386] The central challenge is, therefore, that an attempt must be made to 'square the circle': the liability regime must be as strict as possible but as flexible as necessary. The obvious question is, how could the balance between these requirements be achieved? It is submitted that the only feasible option is to ask for lessons that can be learned from legal approaches which have been implemented vis-à-vis activities that are, in one way or the other, comparable to geoengineering, and to follow the historical precedents of those approaches which have succeeded.

148 As regards certain SRM techniques, in particular SAI, it has been argued that the closest similarity is to the regime of peaceful use of nuclear energy, particularly taking into account the risk of potentially catastrophic transboundary consequences involved with the two activities.[387] Even though it has to be kept in mind that the impacts of nuclear accidents are, due to the Chernobyl and Fukushima disasters, far better studied than those of SRM, both activities are indeed characterised by complex technological and scientific challenges and uncertainties. More generally, the urgent need to find a balance between the interests of the different actors involved, as well as between what is desirable and what is feasible, militates in favour of a "mixed" liability system under which different standards could be

[384] Lin (2013b), p. 141; see also Robock (2012), p. 203.

[385] Horton et al. (2015), p. 227.

[386] But see Horton et al. (2015), p. 226, arguing that in the "absence of a credible liability system, the international community would (arguably) be unlikely to agree to any form of SAI implementation". If this assumption is correct (what seems debatable), then one may say that the existing reservation to develop an appropriate liability regime represents a political strategy to prevent that geoengineering approaches will be carried out in future.

[387] The nuclear liability regime consists of two sets of sub-regimes: the Paris Regime developed under the auspices of the Nuclear Energy Agency of the OECD, and the Vienna Regime established by the International Atomic Energy Agency (IAEA).

applied to different situations and actors. An effective liability regime should also take into account the requirement of providing for financial securities and establishing residual mechanisms such as funds. These basic requirements can be substantiated based on those elements that are common to existing international liability regimes and which could therefore also form the core of a future liability regime for geoengineering.[388]

With regard to the liable actors, most international liability regimes initially focus on one single type of actor, that is first and foremost, exclusively and strictly liable.[389] The actor concerned is usually the entity in control of the activity when an incident occurs, or the entity instituting the transport of hazardous goods respectively.[390] These actors, being responsible for the safety of their operations, are the closest related to the activity concerned and thus best suited to appropriately manage the hazards and take action in case of an incident. Furthermore, exclusive liability avoids the complicated task of establishing which of the several actors involved in, for example, the transport of hazardous material, is liable and it may also prevent the fragmentation of insurance capacity as not every actor involved has to take out insurance.[391] At the same time, all existing regimes acknowledge the existence of exemptions from liability[392] and most regimes also allow for a consideration of any **149**

[388] The following description of common liability elements is based on Saxler et al. (2015), pp. 140–145.

[389] See Horton et al. (2015), p. 244, stating that “it is necessary to recognize that strict liability (as opposed to fault-based) has become the standard in international law, and would almost certainly apply to any SAI liability regime”.

[390] Operator: Art 3 of the Paris Convention on Third Party Liability in the Field of Nuclear Energy of 29 July 1960 (Paris Convention), as amended by the Additional Protocol of 28 January 1964 (956 UNTS 263); Article II(1) of the Vienna Convention on Civil Liability for Nuclear Damage of 21 May 1963 (1063 UNTS 265); Article 3 of the Annex to the Brussels Convention Supplementary to the Convention on Third Party Liability in the Field of Nuclear Energy of 31 January 1963 (Brussels Supplementary Convention), as amended by the Additional Protocol of 28 January 1964 (1041 UNTS 358); Article II(1)(2) of the Convention on the Liability of Operators of Nuclear Ships of 25 May 1962 (Nuclear Ships Convention), American Journal of International Law 57 (1963), p. 268; Articles 6 & 7 of the Lugano Convention. Shipowner: Article III(1) of the Convention on Civil Liability for Oil Pollution Damage of 29 November 1969 (973 UNTS 3), amended by the Protocol to the International Convention on Civil Liability for Oil Pollution Damage of 19 November 1976 (1225 UNTS 355), and revised by the Protocol to amend the International Convention on Civil Liability for Oil Pollution Damage, of 27 November 1992 (1956 UNTS 255); Article 3(1) of the International Convention on Civil Liability for Bunker Oil Pollution Damage (Bunkers Convention) of 23 March 2001, ILM 40 (2001), 1493; Article 7(1) of the HNS Convention.

[391] See International Atomic Energy Agency (IAEA) (2017), p. 1.

[392] E.g., Article 9 of the Paris Convention; Article IV(3) of the Vienna Convention; Article 3(5) of the Annex to the Supplementary Compensation Convention; Article VIII of the Nuclear Ships Convention; Article III(2) of the Oil Civil Liability Convention; Article 3(3) of the Bunkers Convention; Article 7(2) of the HNS Convention; Article 4(5) of the Basel Protocol.

contributory fault on the part of the victim of harm[393] and fault-based liability of other actors.[394]

150 As far as the covered damage is concerned, all existent regimes refer to damage to persons and property.[395] Treaties that were concluded more recently include certain kinds of economic loss[396] and measures of prevention following the occurrence of an incident to minimise and/or prevent further harm.[397] These agreements also address damage to the environment, albeit in different ways. While all treaties provide for compensation of measures of reinstatement,[398] in most instances this only includes actions necessary to reinstate or restore the harmed environment. In contrast, some regimes go beyond that by referring to the introduction of "equivalent [environmental] components into the environment"[399] if the restoration of the original environment is not possible. Furthermore, some regimes, be it expressly or tacitly, include compensation for scientific assessment of the damaged environment.[400] Compensation for harm to the environment which is unrelated to pure economic loss or damage to persons and property is not regulated by any of the regimes concerned.[401]

151 Concerning limitations to liability, all the relevant agreements contain provisions on time limits. In particular, an absolute time limit generally applies which is calculated by referring to the occurrence of the incident in question as the starting

[393] Article IV(2) of the Vienna Convention; Article 3(6) of the Annex to the Supplementary Compensation Convention; Article II(5) of the Nuclear Ships Convention; Article III(3) of the Oil Civil Liability Convention; Article 3(4) of the Bunkers Convention; Article 7(3) of the HNS Convention; Article 4(3) of the Kiev Protocol; Article 9 of the Lugano Convention.

[394] See Article III(4) of the Oil Civil Liability Convention; Article 7(5) of the HNS Convention; Article 5 of the Basel Protocol.

[395] E.g., Article 3(a)(i) & (ii) of the Paris Convention; Article I(7) of the Nuclear Ships Convention; Article 1(6)(a) & (b) of the HNS Convention.

[396] E.g., Article I(f)(iii), (v) & (vii) of the Supplementary Compensation Convention; Article I(6)(a) of the Oil Civil Liability Convention; Article I(9)(a) of the Bunkers Convention; Article 1(6)(c) of the HNS Convention; Article 2(2)(c)(iii) of the Basel Protocol; Article 2(2)(d)(iii) of the Kiev Protocol.

[397] E.g., Section I B(vii)(6) & (ix) of the Protocol to Amend the Convention on Third Party Liability in the Field of Nuclear Energy of 29 July 1960, as amended by the Additional Protocol of 28 January 1964 and by the Protocol of 16 November 1982, of 12 February 2004 (2004 Paris Protocol), https://www.oecd-nea.org/law/paris_convention.pdf, accessed 1 Apr 2022; Article I(f)(vi) & (h) of the Supplementary Compensation Convention; Article 1(9)(b) & (7) of the Bunkers Convention; Article I(6)(b) & (7) of the Oil Civil Liability Convention.

[398] E.g., Section I B(vii)(4) & (viii) of the 2004 Paris Protocol; Article I(f)(iv) & (g) of the Supplementary Compensation Convention; Article I(6)(a) of the Oil Civil Liability Convention; Article 1(9)(a) of the Bunkers Convention; Article 1(6)(c) of the HNS Convention.

[399] Article 2(8) of the Lugano Convention.

[400] Article 2(2)(d) of the Basel Protocol.

[401] It has been stated that the Lugano Convention, which provides for the introduction of equivalents into the damaged environment, comes "very close to providing compensation for damage to the environment *per se,* for introducing the 'equivalent' into the environment is qualitatively different from restoring the environment to its exact pre-existing state" (de La Fayette 2010, p. 340).

point.[402] Almost all regimes establish limits concerning monetary compensation, shaped either by way of minimum[403] and/or maximum amounts with some agreements foreseeing that the limitation of compensation depends on the establishment of a fund by the liable actor.[404] Finally, some liability regimes have a general requirement that the operator provides some kind of financial security.[405] Some agreements contain further obligations relevant to one or several funds that have to be established in advance or establish such funds themselves to provide supplementary compensation. Financial resources are to be provided either by the State party that authorises the activity, by the State party on whose territory the activity is carried out,[406] by the State parties collectively[407] or by the recipients of the hazardous material.[408] With regard to SRM, it has been suggested that operators within the fossil fuel industry should be required to provide funds sufficient for potential future compensation.[409]

[402] See, e.g., Article 8(a) of the Paris Convention; Article VI(1) of the Vienna Convention; Article 9(1) of the Annex to the Supplementary Compensation Convention; Article V(1) of the Nuclear Ships Convention; Article VIII of the Oil Civil Liability Convention; Article 8 of the Bunkers Convention; Article 37(3) of the HNS Convention.

[403] See Article 7(b) & (c) of the Paris Convention; Article V of the Vienna Convention; Article 4 of the Annex to the Supplementary Compensation Convention.

[404] Article V(1) – (3) of the Oil Civil Liability Convention; Article 9(1) – (3) HNS Convention.

[405] Article 10 of the Paris Convention; Article 3(b)(i) of the Brussels Supplementary Convention; Article VII of the Vienna Convention; Article III(2) & (3) of the Nuclear Ships Convention; Article VII of the Oil Civil Liability Convention; Article 7 of the Bunkers Convention; Article 12 of the HNS Convention; Article 14 of the Basel Protocol; Art 11 of and Annex II Part II to the Kiev Protocol. According to Article 12 Lugano Convention, financial security is "[w]here appropriate, taking due account of the risks of the activity", compulsory.

[406] See Section I K (c) of the 2004 Paris Protocol; Article 3(b)(ii) of the Brussels Supplementary Convention.

[407] Article 3(b)(iii) & Article 12 of the Brussels Supplementary Convention; Article III(1)(b) & Article IV of the Supplementary Compensation Convention.

[408] Articles 2(2), 4 & 10 of the Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (Oil Fund Convention) of 18 December 1971 (1110 UNTS 57), amended by the Protocol to the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage of 19 November 1976 (1862 UNTS 509) and revised by the Protocol to amend the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage of 27 November 1992 (1953 UNTS 330). In particular due to the existence and specific design of the compensation funds foreseen by the aforementioned agreements, the oil pollution liability regime is strongly advocated as a model for geoengineering by Horton et al. (2015), pp. 250–259.

[409] Horton et al. (2015), p. 258.

9.7 Conclusion

152 The aforementioned elements offer some useful insights into how a potential future regime of liability for geoengineering damage could be shaped. In particular, the flexible character of many existent agreements facilitates their continued application to changing circumstances as well as newly emerging knowledge and activities. Furthermore, their very existence is evidence of a certain degree of acceptability concerning their underlying guiding principles and institutional architecture. At the same time, it has to be kept in mind that some of the aforementioned treaties have not yet entered into force, a fact that again indicates the existing reluctance on behalf of the community of States towards accepting *any* general framework establishing their liability for harm arising from engaging in 'ultra-hazardous' activities.

153 Therefore, in the absence of an adequately tailored geoengineering liability regime, it can be assumed that the developments identified in Chap. 7 regarding tort litigation will apply to geoengineering activities should any damage occur as a result of a large-scale experiment or deployment. This assumption is justified in view of the comparatively close interrelationship between the climate regime on the one hand and geoengineering on the other, especially considering that the various approaches are all consistent in their aim to contribute to the objectives of the Paris Agreement. This assumption is also reasonable in view of the fact that the challenges posed in the context of climate litigation in connection with establishing a causal nexus between activity and damage are almost equally relevant to geoengineering. Adding to the viability of this approach is the fact that the enforcement of liability claims before national courts does not involve objections that often apply at the level of public international law. In this respect, insofar as the respective tort claims are directed against private actors carrying out the activities in question and in accordance with the polluter-pays principle, it is neither possible to invoke the principle of State immunity nor can the jurisdiction of the courts be challenged by the parties to the dispute. Against this background, geoengineering could, in the future, prove to be a model with regard to international corporate liability for environmental harm.

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