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Regulating Geoengineering Technologies to Address Climate Change: An International Law Perspective

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Abstract: *This research paper delves into the need for an international legal framework to regulate geoengineering technologies as the impacts of climate change become increasingly pressing. The paper explores the ethical and environmental principles that should guide the regulation of these technologies, as well as potential human rights implications. The role of public participation, liability and compensation mechanisms, and the precautionary principle are also examined. The paper stresses the need to consider the perspectives and interests of the Global South and recommends further research on the impact of these technologies on marginalized communities and developing countries. Ultimately, this interdisciplinary paper provides insights and recommendations for the development and governance of geoengineering technologies, contributing to the ongoing conversation on climate change and environmental law.*

Key Words: International Law, Geoengineering Technology, Environmental Law, Governance Framework, International Cooperation

Introduction

The rapidly changing climate of the Earth, largely due to anthropogenic activity, has been identified as a major threat to the planet and its inhabitants (Masson-Delmotte et al., 2018). In response to this threat, various technologies and techniques have been proposed and developed to intentionally modify the Planet's climate and mitigate the effects of climate change over. These proposed interventions, collectively known as geoengineering, include solar radiation management and carbon dioxide removal (Keith, 2013). While these approaches have the capability to lessen the impacts of climate change, they also present a range of ethical, legal, social, and political

challenges that require careful consideration and regulation.

The intent of this research is to examine the international legal framework for regulating geoengineering technologies and to explore the challenges and opportunities for regulating these technologies within an international legal context. The paper will provide an overview of geoengineering technologies, the need for international regulation, and the current state of international law on geoengineering. It will also explore principles for regulating geoengineering under international law, the potential for establishing an international framework for geoengineering regulation, and the challenges and opportunities for

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geoengineering governance. The ambit of the present inquiry shall be constrained to scrutinizing the global legal structure concerning the governance of geoengineering techniques. Specifically, the study will focus on the identification of gaps and limitations in the current legal framework, the analysis of ethical and environmental principles for regulating geoengineering, and the examination of liability and compensation mechanisms for potential harm caused by geoengineering.

The study will also examine the role of public participation in geoengineering governance, the potential impact of geoengineering on the Global South, and the challenges and opportunities for the future of geoengineering regulation. The methodology for this study will involve a comprehensive review of the relevant literature and legal frameworks related to geoengineering regulation, as well as the analysis of case studies and expert opinions. The research will draw upon a range of sources, including international treaties and agreements, academic articles, and reports from international organizations and civil society groups. The study will use a critical and interdisciplinary approach, drawing on principles and insights from environmental law, human rights law, and international governance.

Geoengineering Technologies: An Overview

The preceding chapter expounded upon the subject of geoengineering, which denotes the deliberate and extensive alteration of Earth's natural systems aimed at mitigating or counteracting the repercussions of climate change. The two principal classifications of geoengineering technologies are solar radiation management (SRM) and carbon

dioxide removal (CDR)(Field et al., 2021; Gailhofer et al., 2023) This part presents a comprehensive account of these technologies, elucidating their probable advantages and disadvantages.

Definition and Classification of Geoengineering Technologies

SRM technologies aim to reduce the amount of solar radiation that reaches the Earth's surface(Gailhofer et al., 2023). This can be achieved through various approaches, such as the injection of reflective particles into the upper atmosphere or the deployment of mirrors or reflective surfaces in space. The aim of SRM is to reflect some of the external sunlight back into space, thus reducing the amount of solar energy enthralled by the Earth and potentially cooling the planet(National Academies of Sciences & Medicine, 2021). Carbon dioxide removal (CDR) technologies, conversely, aspire to extract carbon dioxide from the atmosphere and sequester it in diverse reservoirs such as geological formations, oceans, or forests. CDR can be accomplished through a myriad of methods, including afforestation, ocean fertilization, and direct air capture. The objective of CDR is to abate the concentration of carbon dioxide in the atmosphere and consequently ameliorate the consequences of anthropogenic climate change(National Academies of Sciences & Medicine, 2021).

Different Approaches to Geoengineering

The various approaches to geoengineering can be further classified into two types: large-scale and small-scale (Keith et al., 2016). Large-scale approaches involve interventions that have a significant impact on the Earth's climate system, such as the deployment of reflective particles in the upper atmosphere. Small-scale

approaches, on the other hand, involve interventions that have a localized or limited impact, such as afforestation or direct air capture. Another way to categorize geoengineering technologies is by their time scale. Some technologies, such as SRM, are designed to have a rapid and short-term impact on the Earth's climate system, whereas others, such as CDR, are designed to have a longer-term impact and can take decades or even centuries to achieve their intended results (National Academies of Sciences & Medicine, 2021)

Potential Risks and Benefits of Geoengineering

The application of geoengineering technologies exhibits the potential to alleviate the impacts of climate change and curtail the hazards posed to the earth and its occupants. Nonetheless, it is imperative to acknowledge that the implementation of such methods is also accompanied by a diverse array of potential hazards and unanticipated outcomes that necessitate meticulous examination and governance. Certain plausible perils that may arise from the utilization of geoengineering encompass the following (National Academies of Sciences & Medicine, 2021).

Environmental and ecological impacts: Geoengineering interventions can have unintended and negative impacts on ecosystems and biodiversity, such as altering precipitation patterns, reducing the amount of sunlight available for photosynthesis, or changing the chemistry of the oceans.

Social and political impacts: The deployment of geoengineering technologies can have significant social and political impacts, such as exacerbating existing social inequalities, creating winners and losers

among different regions and countries, or creating new geopolitical tensions.

Ethical and governance issues: Geoengineering technologies raise a range of ethical and governance issues, such as the equitable distribution of risks and benefits, the transparency and accountability of decision-making, and the involvement of affected communities in the governance of geoengineering.

Despite these risks, geoengineering technologies also present potential benefits, such as:

Reducing the risks of climate change: The implementation of geoengineering technologies carries the inherent capacity to mitigate the potential dangers of climate change and its concomitant ramifications, including but not limited to the escalating sea levels, the occurrence of unprecedented and devastating weather phenomena, and the loss of biodiversity.

Providing additional time for mitigation and adaptation: Geoengineering technologies can provide additional time for countries and communities to develop and implement more sustainable and resilient strategies for mitigation and adaptation to climate change (National Academies of Sciences & Medicine, 2021).

Cost-effectiveness: The cost-effectiveness of certain geoengineering techniques, such as afforestation and soil carbon sequestration, has been demonstrated to yield favourable outcomes. Moreover, these methods confer collateral benefits, notably the enhancement of soil vigour and amelioration of water quality (Keith & Irvine, 2016).

Rapid response to climate emergencies: In the event of a climate emergency, such as a sudden and catastrophic collapse of the West Antarctic Ice Sheet, geoengineering technologies could provide a rapid response and potentially prevent or mitigate the worst impacts (National Academies of Sciences & Medicine, 2021).

However, the benefits of geoengineering technologies are largely hypothetical and vary on an array of factors, such as the efficacy of the technology, the scale of deployment, and the potential unintended consequences (National Academies of Sciences & Medicine, 2021).

In summary, geoengineering technologies offer potential solutions to the global problem of climate change, but they also present significant risks and uncertainties. The classification of geoengineering technologies into SRM and CDR, and their further categorization into large-scale and small-scale interventions, provides a useful framework for understanding the range of approaches that have been proposed. However, careful consideration and regulation of these technologies are required to ensure that they are deployed in a safe, ethical, and effective manner.

III. The Need for International Regulation of Geoengineering Technologies

Geoengineering technologies have the potential to significantly alter the Earth's climate and environment. While these technologies offer potential solutions to the challenges posed by climate change, they also present a range of risks and uncertainties that require careful consideration and regulation. This chapter will discuss the need for international regulation of geoengineering

technologies and the challenges associated with their regulation.

The Role of Geoengineering in Addressing Climate Change

Geoengineering technologies have garnered considerable attention as prospective methods of countering the deleterious effects of climate change. Two such techniques, namely Solar Radiation Management (SRM) and Carbon Dioxide Removal (CDR) (Gailhofer et al., 2023), have been put forth as complementary strategies for mitigating climate change by limiting the amount of solar radiation reaching the Earth's surface and sequestering carbon dioxide from the atmosphere. Notwithstanding their potential advantages, the implementation of these geoengineering technologies may have considerable and long-term ramifications on the Earth's environment and climate system (Trisos et al., 2018).

Geoengineering's Environmental and Health Impacts of Concern

Geoengineering interventions could have unintended consequences and negative influences on the environment and mortal health. For example, the deployment of reflective particles in the upper atmosphere could alter precipitation patterns, leading to droughts or floods in different regions (Keith et al., 2016). Similarly, the use of ocean fertilization techniques to increase the absorption of carbon dioxide by marine algae could lead to harmful algal blooms or ocean acidification (National Academies of Sciences & Medicine, 2021).

The deployment of geoengineering technologies also raises concerns about the potential impact on human health, particularly

in the Global South. For example, the use of aerosol injections to reflect sunlight back into space could affect the monsoon patterns, which are critical for food security in many regions of the world (Ramanathan & Xu, 2010).

The Limitations of Existing International Legal Frameworks in Regulating Geoengineering International law has a critical role to play in the regulation of geoengineering technologies. However, the existing international legal frameworks for environmental protection and climate change mitigation do not explicitly address geoengineering. The United Nations Framework Convention on Climate Change (Gailhofer et al., 2023) (UNFCCC) and the Paris Agreement are international treaties that prioritize the mitigation and adaptation of climate change impacts. However, they are silent on the complex issue of regulating geoengineering, which refers to the intentional huge-scale exploitation of the Earth's natural systems to neutralize the effects of climate change. The absence of explicit guidance on this subject highlights the need for further research and dialogue to ensure responsible governance of geoengineering activities in the future (Greene, 2000).

The deficiency of a clear lawful framework for regulating geoengineering has led to a patchwork of national and regional regulations and a lack of coordination among different actors. Furthermore, the lack of a clear legal framework has raised concerns about the potential for unilateral deployment of geoengineering technologies by powerful states, which could have negative impacts on vulnerable and marginalized communities (Corner & Pidgeon, 2010). So, the deployment of geoengineering technologies presents a

range of risks and uncertainties that require careful consideration and regulation. International law has a critical role to play in the regulation of geoengineering technologies, but the existing legal frameworks for environmental protection and climate change mitigation are limited in their scope and applicability. The development of an international legal framework for regulating geoengineering (Gailhofer et al., 2023) is essential to ensure that these technologies are deployed in a safe, ethical, and effective manner.

The State of International Law on Geoengineering

This section provides an overview of the existing position of international law on geoengineering. It begins with an overview of the relevant international treaties and agreements and then analyzes the gaps and shortcomings in the current legal framework. Finally, the chapter examines case studies of national approaches to regulating geoengineering.

Overview of the Relevant International Treaties and Agreements

Contemporary international law pertaining to the preservation of the environment and the mitigation of climate change fails to incorporate explicit provisions that pertain to the field of geoengineering. Though, several international treaties and agreements provide some guidance on the regulation of geoengineering. The Convention on Biological Diversity (CBD) (Du, 2017), for example, calls for the regulation of geoengineering in a precautionary and transparent manner and emphasizes the need to take into balance the likely influences on biodiversity and the environment (INDEX, 2004). The London

Convention and Protocol (Gailhofer et al., 2023), which standardizes the dumping of wastes at sea, also provides some guidance on the management of oceanic fertilization (Verlaan, 2013). The Paris Agreement, although it does not explicitly mention geoengineering, calls for the use of a precautionary approach and the consideration of the potential impacts of climate interventions (UFCC, 2016). The Intergovernmental Panel on Climate Change (IPCC) (Du, 2017) has also provided guidance on the ethical, social, and environmental considerations for the deployment of geoengineering technologies (Change, 2007).

Analysis of the Gaps and Shortcomings in the Current Legal Framework

Despite the existing guidance from international treaties and agreements, the current legal framework for regulating geoengineering is fragmented and lacks coherence. The guidance is provided by the existing international treaties and agreements in general and non-binding, and there is no clear legal framework for regulating geoengineering (Medvedieva et al., 2018). There are also gaps in the legal framework with respect to responsibility and reimbursement for potential harm caused by geoengineering. The London Convention and Protocol fail to furnish precise directives concerning accountability and indemnification concerning ecological harm resulting from ocean fertilization (EPA, 2023). Similarly, there is no clear guidance on liability and compensation for the potential negative impacts of SRM on vulnerable communities and ecosystems (National Academies of Sciences & Medicine, 2021).

Case Studies of National Approaches to Regulating Geoengineering

In the absence of a clear international legal framework for regulating geoengineering, some countries have developed their own national approaches to regulating geoengineering. These approaches vary in their scope and level of detail. For example, the United Kingdom has developed a voluntary code of conduct for research into geoengineering, which emphasizes the need for transparency, consultation, and stakeholder engagement (Society, 2009b). Germany has developed a research framework for geoengineering that includes the consideration of ethical, social, and environmental impacts (Morrow, 2017). The United States has taken a different approach, with a focus on federal research and development programs rather than regulatory frameworks. However, the National Environmental Policy Act (NEPA) requires federal agencies to conduct environmental impact assessments for actions that may have a significant impact on the environment, which could potentially apply to geoengineering ("National Environmental Policy Act," 1969). So, the current state of international law on geoengineering is fragmented and lacks coherence. While there is some guidance from existing international treaties and agreements, there is no clear legal framework for regulating geoengineering. The existing guidance also lacks detail and is non-binding. National approaches to regulating geoengineering vary in their scope and level of detail, highlighting the need for a clear and coherent international legal framework for regulating geoengineering.

V. Principles for Regulating Geoengineering under International Law

The regulation of geoengineering under international law must be guided by a set of principles that reflect the ethical, environmental, and human rights considerations that underpin the need for regulation. This chapter will discuss the principles for regulating geoengineering under international law, including ethical considerations, environmental principles, and human rights considerations.

Ethical Considerations in Regulating Geoengineering

The deployment of geoengineering technologies raises a range of ethical considerations that must be taken into account in the regulation of these technologies. One of the key ethical considerations is the potential for unintended consequences, which could have significant and long-lasting impacts on the environment and human health (Du, 2017; Gailhofer et al., 2023). The precautionary principle, which emphasizes the need to avoid harm in the face of scientific uncertainty, should guide the regulation of geoengineering (CBD, 2010). Another ethical consideration is the potential for the unequal distribution of the benefits and risks of geoengineering. The deployment of geoengineering technologies could have differential impacts on different regions and communities, and the regulation of these technologies must take into account the potential for social and environmental justice (Corner & Pidgeon, 2010).

Environmental Principles for Regulating Geoengineering

The regulation of geoengineering must be guided by a set of environmental principles that reflect the need to protect and conserve the Earth's ecosystems and biodiversity. One

of the key environmental principles is the need to minimize harm to the environment and biodiversity, including both direct and indirect impacts. The regulation of geoengineering must also take into account the potential for irreversible and long-lasting impacts on the environment and the need to avoid such impacts (CBD, 2010). The regulation of geoengineering must also reflect the need to consider the interactions between different ecosystems and the potential for cascading impacts. For example, the deployment of ocean fertilization techniques could have unintended consequences for marine ecosystems and the global carbon cycle (National Academies of Sciences & Medicine, 2021).

Human Rights Considerations in Regulating Geoengineering

The regulation of geoengineering must also take into account the potential impacts on human rights, particularly the rights of vulnerable and marginalized communities. The deployment of geoengineering technologies could have significant impacts on food security, water availability, and health, particularly in the Global South. The regulation of geoengineering must take into account the potential for these impacts and the need to avoid disproportionate and unjust impacts on vulnerable communities (Ramanathan & Xu, 2010). The regulation of geoengineering must also reflect the need to ensure that the deployment of these technologies does not undermine other human rights, such as the right to a healthy environment or the right to participate in decision-making processes. The regulation of geoengineering must take into account the potential for social and environmental justice and the need to ensure that vulnerable and marginalized communities have a voice in the

decision-making process(Corner & Pidgeon, 2010). So, the regulation of geoengineering under international law must be guided by a set of principles that reflect the ethical, environmental, and human rights considerations that underpin the need for regulation. The principles of the precautionary approach, social and environmental justice, and the protection of biodiversity and ecosystems are critical in guiding the regulation of geoengineering.

VI. Establishing an International Framework for Regulating Geoengineering

The regulation of geoengineering requires a coordinated, multilateral approach at the international level. This chapter will discuss the role of the United Nations in regulating geoengineering, the need for a multilateral approach, and options for establishing a global legal structure for regulating geoengineering.

The Role of the United Nations in Regulating Geoengineering

The United Nations (UN) has a critical role to play in the regulation of geoengineering. The UN Framework Convention on Climate Change (UNFCCC)(Du, 2017) and the Paris Agreement are key international agreements that provide guidance on addressing climate change. However, neither of these agreements explicitly addresses geoengineering. The UN has also established several bodies that could potentially play a role in regulating geoengineering. For example, the Intergovernmental Panel on Climate Change (IPCC)(Du, 2017) has provided guidance on the ethical, social, and environmental considerations for the deployment of geoengineering technologies(Masson-Delmotte et al., 2018). The Convention on Biological Diversity (CBD) also provides

guidance on the regulation of geoengineering in a precautionary and transparent manner(CBD, 2010).

The Need for a Multilateral Approach to Regulating Geoengineering

The regulation of geoengineering requires a multilateral approach that involves cooperation and coordination among different actors. The lack of a clear legal framework for regulating geoengineering has led to a patchwork of national and regional regulations and a lack of coordination among different actors. A multilateral approach to regulating geoengineering would enable the development of a clear and coherent legal framework that reflects the principles of the precautionary approach, social and environmental justice, and the protection of biodiversity and ecosystems. It would also enable the development of a coordinated research agenda that addresses the key uncertainties and knowledge gaps related to the potential impacts of geoengineering (National Academies of Sciences & Medicine, 2021).

Options for Establishing an International Legal Framework for Regulating Geoengineering

There are a number of options for establishing an international legal framework for regulating geoengineering. One option is to develop a new international treaty or agreement specifically focused on geoengineering. Such a treaty or agreement could establish clear guidelines for the deployment of geoengineering technologies, including principles for ethical, environmental, and human rights considerations. Another option is to amend existing international treaties and agreements, such as the UNFCCC or the CBD, to explicitly address

geoengineering. This would require a consensus among the parties to the treaty or agreement and could be a time-consuming and challenging process. A third option is to establish a new international body or mechanism specifically focused on the regulation of geoengineering. Such a body or mechanism could provide guidance on the regulation of geoengineering and coordinate research efforts to address the key uncertainties and knowledge gaps related to the potential impacts of geoengineering (National Academies of Sciences & Medicine, 2021). So, the regulation of geoengineering requires a coordinated, multilateral approach at the international level. The United Nations has a critical role to play in the regulation of geoengineering, but the lack of a clear legal framework for regulating geoengineering has led to a patchwork of national and regional regulations and a lack of coordination among different actors. Options for establishing an international legal framework for regulating geoengineering include developing a new international treaty or agreement, amending existing international treaties and agreements, or establishing a new international body or mechanism specifically focused on the regulation of geoengineering.

VII. The Precautionary Principle and Geoengineering

The precautionary principle (Du, 2017) is a key guiding principle for regulating geoengineering. This chapter will discuss the precautionary principle as a guiding principle in regulating geoengineering, case studies of its application in other environmental contexts, and the challenges of applying the precautionary principle to geoengineering.

Precautionary Principle in Geoengineering Regulation

This theory is a notion of international environmental law (Gailhofer et al., 2023) that emphasizes the need to avoid harm in the face of scientific uncertainty. The principle is based on the idea that in situations where there is scientific uncertainty about the potential impacts of an activity, it is better to err on the side of caution and take measures to avoid harm (CBD, 2010). The precautionary principle is particularly relevant to the regulation of geoengineering, which involves a range of potential environmental and human health impacts that are not fully understood. The deployment of geoengineering technologies could have significant and long-lasting impacts on the environment, and the precautionary principle provides a framework for regulating these technologies in a way that minimizes the potential for harm.

Precautionary Principle in Environmental Contexts: Case Studies

It has been applied in a number of other environmental contexts, including the regulation of genetically modified organisms (GMOs), the regulation of chemicals, and the regulation of nuclear power. In each of these contexts, the precautionary principle has been used to guide decision-making in the face of scientific uncertainty (CBD, 2010). For example, in the regulation of GMOs, the precautionary principle has been used to guide decision-making about the potential risks and benefits of these technologies. The European Union has adopted a precautionary approach to the regulation of GMOs, which requires a case-by-case assessment of the potential risks and benefits of these technologies (McNelis, 2000).

The Challenges of Applying the Precautionary Principle to Geoengineering

Applying the precautionary principle to the regulation of geoengineering presents a number of challenges. One of the key challenges is the potential for scientific uncertainty and the need to make decisions in the face of this uncertainty. The deployment of geoengineering technologies involves a range of potential environmental and human health impacts that are not fully understood, and the regulation of these technologies must take into account the potential for unintended consequences (National Academies of Sciences & Medicine, 2021). Another challenge is the need to balance the potential risks and benefits of geoengineering. The deployment of geoengineering technologies could have substantial and long-lasting impacts on the environment and human health, but these technologies could also provide a means of mitigating the consequences of climate change (Du, 2017). The regulation of geoengineering must consider both the potential risks and benefits of these technologies and ensure that the benefits outweigh the potential risks (Ott & Neuber, 2020). So, the precautionary principle is a key guiding principle for regulating geoengineering. The principle has been applied in a number of other environmental contexts, including the regulation of GMOs and chemicals, and provides a framework for regulating geoengineering in a way that minimizes the potential for harm. However, the use of the precautionary principle in geoengineering presents a number of challenges, including the potential for scientific uncertainty and the need to balance the potential risks and benefits of these technologies.

VIII. Liability and Compensation for Geoengineering

The deployment of geoengineering technologies raises a range of potential risks and harms to the environment and human health (Du, 2017). As a result, it is necessary to consider the establishment of liability and compensation mechanisms to address any negative impacts that may arise. This chapter will discuss the need for liability and compensation mechanisms for potential harm caused by geoengineering, an analysis of existing legal frameworks for liability and compensation in other environmental contexts, and proposals for a liability and compensation framework for geoengineering.

The Need for Liability and Compensation Mechanisms for Potential Harm Caused by Geoengineering

The implementation of geoengineering methodologies possesses the potential to yield substantial and enduring repercussions on the ecological and human welfare domains, encompassing multifaceted ramifications on the intricate interrelationships within ecosystems, the variation in the genetic make-up of different species, and the availability and accessibility of sustenance. The deployment of these technologies could also have differential impacts on different regions and communities, leading to potential social and environmental injustices (Corner & Pidgeon, 2010). Given these potential risks and harms, it is necessary to consider the establishment of liability and compensation mechanisms to address any negative impacts that may arise. Liability and compensation mechanisms could provide a means of holding parties responsible for any negative impacts that result from the deployment of geoengineering technologies and could provide a means of compensating

those who are harmed (National Academies of Sciences & Medicine, 2021).

Analysis of Existing Legal Frameworks for Liability and Compensation in Other Environmental Contexts

There are various legal frameworks available to address liability and compensation in different environmental contexts that could potentially serve as valuable references for the development of a liability and compensation framework for geoengineering. For instance, the International Oil Pollution Compensation Funds offer a mechanism for compensating individuals impacted by oil pollution (Parashar, 2021). This framework entails a tax on oil obtained by participating countries, and compensation is paid out to those who have incurred damage as a result of the oil pollution. Additionally, the Convention on Civil Liability for Damage Resulting from Activities Dangerous to the Environment is another pertinent legal framework that provides a framework for liability and compensation for damage resulting from hazardous activities. This convention stipulates that parties must obtain insurance or provide other financial security to cover potential liability for harm caused by hazardous activities ("Convention on Civil Liability for Damage resulting from Activities Dangerous to the Environment (ETS No. 150)," 1993).

Proposals for a Liability and Compensation Framework for Geoengineering

There are several proposals for the improvement of a liability and compensation framework for geoengineering. One proposal is to establish a global fund for compensation that would be financed by contributions from parties deploying geoengineering technologies. The fund would provide compensation for those who are harmed by

the deployment of these technologies (Reynolds, 2019). Another proposal is to establish liability and compensation frameworks at the national or regional level. These frameworks could include mandatory insurance or financial security requirements for parties deploying geoengineering technologies, as well as mechanisms for determining liability and providing compensation for those who are harmed (Proelss & Steenkamp, 2023). So, the deployment of geoengineering technologies could have considerable and long-lasting influences on the environment and human health. As a result, it is necessary to consider the establishment of liability and compensation mechanisms to address any negative impacts that may arise. An analysis of existing legal frameworks for liability and compensation in other environmental contexts could provide guidance for the growth of a burden and compensation framework for geoengineering. Proposals for a liability and compensation framework for geoengineering include the formation of a global fund for reimbursement and the development of accountability and compensation frameworks at the national or regional level.

IX. Public Participation and Geoengineering

The development and deployment of geoengineering technologies could have significant impacts on the environment and human health. As a result, it is important to consider the role of public participation in decision-making regarding geoengineering. This chapter will discuss the role of public participation in decision-making regarding geoengineering, case studies of public participation in other environmental contexts, and proposals for incorporating public

participation in the governance of geoengineering.

The Role of Public Participation in Decision-Making Regarding Geoengineering

Public participation is an important aspect of environmental governance, as it provides a means of incorporating the views and perspectives of affected communities into decision-making processes. Public participation can also help to build public trust and support for environmental decision-making (McNie, 2007). The deployment of geoengineering technologies could have significant impacts on the environment and human health, and it is important to consider the role of public participation in decision-making regarding these technologies. Public participation can provide a means of incorporating the views and perspectives of affected communities into decision-making processes and can help to ensure that the deployment of these technologies is socially and environmentally responsible (Biermann et al., 2009).

Case Studies of Public Participation in Other Environmental Contexts

Public participation has been used in several other environmental contexts, including the regulation of genetically modified organisms (GMOs) and regulation of chemicals. In each of these contexts, public participation has provided a means of incorporating the views and perspectives of affected communities into decision-making processes (McNelis, 2000). For example, in the regulation of GMOs, public participation has been used to engage the public in discussions about the potential risks and benefits of these technologies. In the European Union, public participation is an important part of the regulatory process for

GMOs, and the public is given the opportunity to provide comments and feedback on proposed regulations (Ching, 2007; Wynne, 2001).

Proposals for Incorporating Public Participation in the Governance of Geoengineering

There are a number of proposals for incorporating public participation in the governance of geoengineering. One proposal is to establish a public participation process for the assessment and regulation of geoengineering technologies. This process could include public consultations, public hearings, and opportunities for public comment on proposed regulations (Biermann et al., 2009). Another proposal is to establish a mechanism for public oversight of geoengineering research and deployment. This mechanism could include the establishment of a public advisory committee or the development of a citizen science program to monitor the impacts of geoengineering technologies (National Academies of Sciences & Medicine, 2021). So, public participation is an important aspect of environmental governance, as it provides a means of incorporating the views and perspectives of affected communities into decision-making processes. The deployment of geoengineering technologies could have significant impacts on the environment and human health, and it is important to consider the role of public participation in decision-making regarding these technologies. Case studies of public participation in other environmental contexts could provide guidance for the incorporation of public participation in the governance of geoengineering. Proposals for incorporating public participation in the governance of

geoengineering include the establishment of a public participation process for the assessment and regulation of geoengineering technologies and the establishment of a mechanism for public oversight of geoengineering research and deployment.

X. Geoengineering Governance and the Global South

Geoengineering technologies have the potential to significantly impact developing countries and marginalized communities. As a result, it is important to consider the perspectives and interests of the Global South in the development and governance of geoengineering technologies. This chapter will discuss the potential impact of geoengineering on developing countries and marginalized communities, the need for a geoengineering governance framework that considers the perspectives and interests of the Global South, and proposals for a more inclusive and equitable geoengineering governance framework.

The Potential Impact of Geoengineering on Developing Countries and Marginalized Communities, could have negative impacts on food security in developing countries (IPCC Expert Meeting on Geoengineering, 2011). Similarly, the deployment of carbon dioxide removal technologies could have differential impacts on different regions and communities, with some regions potentially benefiting from the technology and others experiencing negative impacts (Preston, 2013).

The Need for a Geoengineering Governance Framework that Takes into Account the Perspectives and Interests of the Global South Given the potential impact of geoengineering on developing countries and marginalized communities, it is important to consider the perspectives and interests of the Global South in the development and

governance of these technologies. This could include the incorporation of perspectives from the Global South in decision-making processes, the consideration of the potential impact of these technologies on developing countries and marginalized communities, and the development of policies and regulations that take into account the perspectives and interests of the Global South (McLaren & Corry, 2021).

Proposals for a More Inclusive and Equitable Geoengineering Governance Framework

There are a number of proposals for a more inclusive and equitable geoengineering governance framework. One proposal is to establish a geoengineering governance framework that includes representatives from developing countries and marginalized communities. This could include the establishment of a geoengineering governance body that is representative of the global community and includes representatives from developing countries and marginalized communities (Preston, 2013). Another proposal is to establish a mechanism for providing financial and technical support to developing countries to enable them to participate in the development and governance of geoengineering technologies. This could include the establishment of a geoengineering fund that provides financial support to developing countries for research and development in geoengineering, as well as for the development of policies and regulations that take into account the perspectives and interests of the Global South (Tedsen & Homann, 2013). So, the deployment of geoengineering technologies could have significant impacts on developing countries and marginalized communities. As a result, it is important to consider the perspectives and interests of the Global South in the

development and governance of these technologies. Proposals for a more inclusive and equitable geoengineering governance framework include the establishment of a geoengineering governance framework that includes representatives from developing countries and marginalized communities and the establishment of a mechanism for providing financial and technical support to developing countries to enable them to participate in the development and governance of geoengineering technologies.

XI. The Future of Geoengineering Regulation: Challenges and Opportunities

Regulating geoengineering technologies presents a number of challenges, including the rapidly changing technological landscape, the potential for unanticipated impacts, and the need for international cooperation. This chapter will discuss the challenges of regulating geoengineering in a rapidly changing technological landscape, the potential for international cooperation and innovation in geoengineering regulation, and the role of civil society in shaping the future of geoengineering regulation.

The Challenges of Regulating Geoengineering in a Rapidly Changing Technological Landscape

Regulating geoengineering technologies presents a number of challenges, particularly in a rapidly changing technological landscape. New technologies are constantly being developed, and existing technologies are being improved and modified. This can make it difficult to establish a regulatory framework that is flexible enough to accommodate changing technological developments (Meyer, 2019).

Additionally, the potential for unanticipated impacts of geoengineering technologies can make it difficult to establish

effective regulations. There is still much that is not known about the potential impacts of these technologies, and the long-term effects of these technologies are still uncertain (Society, 2009a).

The Potential for International Cooperation and Innovation in Geoengineering Regulation

Despite the challenges of regulating geoengineering technologies, there is potential for international cooperation and innovation in geoengineering regulation. The development and deployment of these technologies present a unique opportunity for international cooperation, as these technologies have the potential to impact countries and communities around the world (Biermann et al., 2009). International cooperation could help to ensure that regulations are effective in mitigating potential harm, while also ensuring that these technologies are deployed in a socially and environmentally responsible manner. Additionally, innovation in the development of new regulatory frameworks and technologies could help to address some of the challenges associated with regulating geoengineering technologies (Meyer, 2019).

The Role of Civil Society in Shaping the Future of Geoengineering Regulation

Civil society can play an important role in shaping the future of geoengineering regulation. Civil society organizations can provide input into regulatory processes, advocate for more effective regulations, and raise public awareness about the potential impacts of these technologies (Preston, 2013). Additionally, civil society organizations can help to ensure that the perspectives and interests of marginalized communities and developing countries are taken into account in

the development and governance of these technologies. Civil society organizations can also help to monitor the deployment of these technologies and provide feedback to regulatory bodies (National Academies of Sciences & Medicine, 2021). So, regulating geoengineering technologies presents a number of challenges, including the rapidly changing technological landscape and the potential for unanticipated impacts. However, there is potential for international cooperation and innovation in geoengineering regulation, and civil society can play an important role in shaping the future of geoengineering regulation. The development and deployment of these technologies present a unique opportunity for international cooperation, and civil society organizations can help to ensure that the perspectives and interests of marginalized communities and developing countries are taken into account in the development and governance of these technologies.

XII. Conclusion

This research paper has provided an in-depth analysis of the need for international regulation of geoengineering technologies to address climate change. The paper has highlighted the potential risks and benefits of geoengineering, and the limitations of existing international legal frameworks in regulating these technologies. It has also discussed the principles for regulating geoengineering under international law, the need for establishing an international framework for regulating geoengineering, and the importance of incorporating the precautionary principle, liability and compensation, and public participation in the governance of geoengineering. Furthermore,

the paper has discussed the potential impact of geoengineering on developing countries and marginalized communities, the need for a geoengineering governance framework that considers the perspectives and interests of the Global South, and the challenges and opportunities associated with the future of geoengineering regulation. This research paper has contributed to the literature on climate change and environmental law and has provided insights and recommendations for future research and action.

The key findings of this research paper are that regulating geoengineering technologies presents a number of challenges, including the rapidly changing technological landscape, the potential for unanticipated impacts, and the need for international cooperation. However, there is potential for international cooperation and innovation in geoengineering regulation, and civil society can play an important role in shaping the future of geoengineering regulation. The development and deployment of these technologies present a unique opportunity for international cooperation, and civil society organizations can help to ensure that the perspectives and interests of marginalized communities and developing countries are considered in the development and governance of these technologies.

The implications for international law and policy on climate change and geoengineering are that there is a need for an international legal framework that considers the potential risks and benefits of geoengineering, as well as the principles of environmental ethics and human rights. This legal framework should also consider the perspectives and interests of the Global South and should incorporate mechanisms for public participation, liability

and compensation, and the precautionary principle.

The directions for future research and action include the need for further research on the potential impact of geoengineering on developing countries and marginalized communities, as well as the need for research on the potential unintended consequences of geoengineering. Additionally, further research is needed on the development and implementation of effective geoengineering governance frameworks that are equitable and inclusive.

In conclusion, regulating geoengineering technologies is a complex and challenging task that requires a multilateral and cooperative approach. The development and deployment of these technologies present a unique opportunity for international cooperation but also require careful consideration of the potential risks and benefits, as well as the ethical and human rights implications. This research paper has provided insights and recommendations for the development and governance of geoengineering technologies and has contributed to the literature on climate change and environmental law.

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