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Effective control mechanisms of research on climate engineering techniques for the public good—The London Protocol regulatory approach as a role model

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Climate engineering, including Carbon Dioxide Removal and Solar Radiation Modification techniques, increasingly gets into the public discussion on effective climate change policies. As most of these techniques are still in their infancy, the critical question arises whether and how *in situ* research and development should be controlled and governed by competent governmental authorities. In this context, public funding may serve as a pivotal factor alongside appropriate regulatory approaches and may itself also be regulated by legal mechanisms. We here argue that the London Protocol, that includes regulation of research into marine geoengineering, is a promising role model also for regulating other climate engineering approaches, including -if ever appropriate- solar radiation modification techniques. We propose to consider the London Protocol as a role model for governance schemes to be developed for emerging research and possible deployment efforts regarding climate engineering.

KEYWORDS

marine geoengineering, climate engineering, governance, carbon dioxide removal, solar radiation modification

Introduction

In its "Special report on global warming of 1.5°C" the Intergovernmental Panel on Climate Change (IPCC, 2018) made the following clear statements: First, all options for reducing emissions must be implemented as quickly as possible. Secondly, an examination of the various political and scientific scenarios shows that supplementary measures to remove carbon dioxide from the atmosphere (carbon dioxide removal, CDR) will be necessary in each 1.5°C scenario analyzed by IPCC (Lawrence et al., 2018). The most recent IPCC assessment report (IPCC, 2022) concludes that the deployment of CDR is now unavoidable if net zero CO_2 or net zero greenhouse gas emissions are to be achieved, a necessary condition to stabilize temperature (Allen et al., 2009). CDR measures therefore appear necessary to reach promised climate targets, such as specified in the Paris Agreement (UNFCCC, 2015). Deployment of CDR technologies, sometimes called negative emissions technologies, may also be needed when temperatures rise significantly above 1.5 or 2°C and this temperature "overshoot" must be reversed (Prütz et al., 2023). To remain on pathways consistent with promised climate targets, large-scale implementation

of CDR could become necessary already in the next few years, depending on the success, in fact on the level of failure, in reducing emissions (IPCC, 2022). The IPCC also addresses arguments for and against Solar Radiation Management (SRM), that are receiving renewed attention particularly in the context of "shaving the peak" in temperature overshoot scenarios (Baur et al., 2023). In essence the IPCC did not consider SRM in its scenarios (IPCC, 2022).

The debate about the possible use of climate engineering[1] techniques has gained enormous momentum and is heavily discussed in the scientific community (e.g., NASEM, 2019, 2021a,b; GESAMP, 2019). The debate is particularly controverse with respect to SRM, with some scientists calling for more research (NASEM, 2021a), some for a "non-use agreement" (Biermann et al., 2022). Despite repeated calls for more research into developing adequate governance of CDR or SRM (e.g., NASEM, 2021a,b), internationally agreed protocols are lacking on the governance of in situ experiments and, even more so, of a possible deployment of most climate engineering approaches.

Parties to the International Regime for the control of dumping of wastes and other matter into the marine environment (London Protocol, LP) have decided in 2022 to consider whether and how to regulate four "emerging" marine geoengineering techniques[2]. In 2023, the statement was reiterated and the need for regulation was emphasized, noting that, depending on project specifics, unregulated use of any of the four techniques has the potential to cause deleterious effects that are widespread, long-lasting or severe (Summary Report—LC 45/17)[3]. The Contracting Parties also agree in the statement of 2023: "In addition, the governing bodies are of the view that there are risks of adverse environmental impacts of these techniques with limited knowledge of their effectiveness, and as such activities other than legitimate scientific research should be deferred."

The following chapter examines the question of whether and how governments should regulate and oversee *in situ* research in the area of climate intervention. To answer this question, the regulatory concept of the international treaty "London Protocol" is analyzed and evaluated. It will be discussed whether the conceptual approach of LP could serve as a role model for governing research of other and potentially all climate engineering techniques. Furthermore, it is explained how control can be facilitated through public research funding. Finally, we will make some remarks concerning private funding of such *in situ* research activities.

Necessity of regulating *in situ* climate engineering research

So far, most techniques in the field of climate engineering are not ready for deployment for several reasons. The effectiveness concerning climate change mitigation has not been sufficiently proven in most cases and there are significant knowledge gaps with regard to the effects on the environment as well—for some techniques—the societies. This has also been concluded by—among others—international groups of scientists in the field of marine geoengineering (GESAMP, 2019), terrestrial and marine CDR (NASEM, 2019, 2021b) and SRM (NASEM, 2021a).

A decision on the use of a technology to counteract climate change can and should only be made once sufficient knowledge is available regarding both its actual contribution to climate protection and its impact on people, the environment and society as a whole. It must also be ensured that research and potential deployment of climate engineering techniques do not undermine efforts with regard to emission reductions, that are in any case the most reliable approach to limit global warming. However, because even ambitious emission reductions are deemed insufficient to reach promised climate targets, there is an urgent need for developing reliable CDR.

Against this background, it is clear that the discussion about appropriate "governance" is timely and must currently refer to the research and testing of these techniques. In this respect, a distinction must be made between theoretical studies and analyses "at the desk", e.g., through modeling, on the one hand, and field trials on the other hand. Only the latter can result in effects on the environment, including possible risks from multiple field trials conducted in overlapping or adjacent areas and having compound effects, or otherwise influencing and possibly invalidating the results of carefully designed studies. A reliable assessment of environmental impacts of marine CDR can, however, not rely on lab experiments alone that, by construction, exclude most of the environment, but will need to additionally consider results of field experiments.

Should research involving field trials be regulated and overseen by competent governmental authorities? In our opinion, there are six main arguments in favor of this: First, the climate policy challenges are about the future of mankind. While it is unlikely that the "earth" is about to collapse, the level of temperature rise and changes in correlated climate variables will determine the extent and quality of the negative to disastrous effects on humans and the environment for many generations to come. Given scientific evidence that the deployment of CDR techniques will be probably unavoidable at least to some extent if net zero CO_2 or net zero greenhouse gas emissions are to be achieved (IPCC, 2022), it is necessary and urgent to decide which technique should be further researched in the field and potentially developed. Such decisions are to be made by people legitimatized by the society. Second, society needs evidence-based information of how effective a technique is to mitigate climate change and what risks it imposes on the society and the environment. Such information can only be provided by high-quality and responsible research. Given the urgency and the importance of identifying solutions with regard to climate change mitigation, it is in the interest of the society that only this kind of

1 In scientific papers, often the term "climate intervention" is used instead of "climate engineering". In this paper, we stick to the latter, in order to emphasize that we focus on—once a technique will be deployed—very large-scale intervention with a potentially very significant effect on the ecosystems. The large scale is required to be climate effective.

2 https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/LC_LP/LP%20LC%20Statement%20on%20Marine%20Geoengineering_%20LC%2044-17%20annex%202.pdf

3 The documents of London Protocol are not publicly accessible. In order to get access to most documents an account for a public user has to be established under: https://webaccounts.imo.org/Common/WebLogin.aspx?App=IMODOCS&ReturnUrl=https%3A%2F%2Fdocs.imo.org%2FCategory.aspx%3Fcid=3&error_message=interaction_required.

research is undertaken. This is what LP calls "legitimate scientific research". Third, not only deployment, but also field testing can cause significant negative effects on people and the environment, especially if field testing reaches larger scales or intensities. Keeping these effects to a minimum is in the public interest and cannot be left to researchers or companies alone. Fourth, government governance seems appropriate to ensure that rules developed for *in situ* research projects apply not only to publicly funded, but also to privately funded research. Fifth, research is not necessarily carried out in the public interest. This is due, on the one hand, to the fact that research content and methods are aligned with the reward systems of research (peer reviewed publications, research funds and fashionable topics) that follow a particular logic that does not necessarily coincide with the interests of the common good (Verlaan, 2013). The pressure to be successful may, for example, influence how remaining uncertainties are recognized, assessed and dealt with. Sixth, in addition to traditional public funding of research, current research into CDR is developing at an increasingly rapid rate and volume funded by philanthropy and also performed by start-ups that are getting money for research by forward (or sometimes the backward) selling of carbon credits or from direct investment into the companies. The economic interest could derail from the public good. In the case of "private donors" such as foundations or corporations, unstated agendas may be associated with the research projects, that are not necessarily in line with the public good perspective. While research funded by "private donors" or performed by private companies can have different incentives and different rules of transparency compared to research funded by taxpayers, there are strong arguments that research involving field trials should follow common standards. This could only be ensured by publicly legitimized regulations.

These six considerations argue for control and governance by government bodies that are in principle legitimatized to represent the public good perspective and, at least in democratic societies, are themselves subject to public scrutiny.

The regulatory concept of London Protocol—a model for regulating climate engineering field experiments?

The London Protocol (LP) to the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Convention, LC), like the Convention itself, is an independent international treaty that was adopted in 1996 and entered into force in 2006[4]. Both treaties, LC and LP, implement the regulatory requirements of the United Nations Convention on the Law of the Sea (UNCLOS), particularly Articles 194 and 197 of UNCLOS.

Both LP and LC aim to prevent negative effects on the marine environment that may result from the discharge of waste or other materials. They do not cover, first, in principle, land-based inputs to the marine environment; second, inputs resulting from resource extraction; and third, those inputs that arise as a result of normal ship operations. These discharges are regulated by regional regimes (e.g., OSPAR, HELCOM) or by MARPOL, adopted under the auspices of the IMO.

LP provides for much stricter regulations than LC with respect to dumping of wastes and other materials. Under LP, there is a general prohibition with exceptions according to a list of seven categories of waste that may be dumped into the marine environment under certain conditions. The LP is intended to eventually replace the LC, and countries who implement the LP are deemed to also be compliant with the LC.

Despite this stricter and modern approach, LP has only 54 states parties so far, while 87 states have ratified the LC. LP and LC contracting states consult together. Furthermore, LC and LP have agreed that only LP will be amended. As a rule, LC states unofficially recognize LP's requirements.

In 2013, States Parties unanimously adopted an amendment to the London Protocol on "marine geo-engineering"[5]. The Amendment has not yet entered into force because two-thirds of the States Parties have not yet implemented and ratified the Amendment[6].

The amendment represents a framework regulation for marine geo-engineering techniques, which only applies to those techniques that are listed in Annex 4 (new). In this case, they require approval by the competent authority of the respective contracting state. The prerequisite for approval is that there are no negative effects on the marine environment. In this respect, Annex 5 provides for a structured assessment of environmental effects. As explained above, the LP Parties are currently considering the listing of four additional MGE techniques.

Currently, Annex 4 only mentions "ocean fertilization". The basic objective of the Amendment with respect to ocean fertilization is clearly stated in Annex 4. Only research projects ("legitimate scientific research") are eligible for approval. All other projects are therefore expressively prohibited (Ginzky and Frost, 2014).

The Amendment provides for an innovative governance approach for research projects, which will be explained below. This approach comprises five core elements:

1. Only research projects are to be allowed to proceed. The assumption is that there are still too many gaps in knowledge for commercial deployment projects to be justifiable because of their potential negative effects on humans and/or the environment.

4 The text of LC and LP can be found here: https://www.imo.org/en/OurWork/Environment/Pages/London-Convention-Protocol.aspx.

5 The resolution entailing the text of the amendment of London Protocol could be found here: https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/LC_LP/LP.4(8).pdf.

6 In fact, only six Contracting Parties have accepted or ratified the 2013 Amendment although the amending resolution was unanimously adopted in 2013. The reasons seem to be manifold inter alia: reluctance to accept international commitments and the resources needed to run the internal processes. Beyond those reasons, for most Contraction Parties there was no immanent need to ratify the amendment because they did not see themselves confronted by Ocean Fertilization research projects, neither due to national research activities nor concerning potential effects through such research projects.

2. The amendment establishes criteria for determining whether a project is a "legitimate" research project. These criteria are found in the new Annex 5, which has six criteria:

   i. The research project will contribute to scientific knowledge.
   ii. An accepted research method will be used. It should allow for peer review and be based on the "best available scientific knowledge and techniques".
   iii. A peer review shall be conducted prior to project implementation.
   iv. Evidence must be provided that the research content and design are not influenced by economic interests. Direct financial benefits must not be gained.
   v. The researchers must commit themselves to publishing their research results, data and research outcomes.
   vi. The required financial resources are available.

   The definition of such criteria to differentiate research from deployment is something new under international law and therefore by itself a remarkable step ahead (Verlaan, 2013).
3. Annex 5 contains requirements for a structured Environmental Impact Assessment.

   Annex 5 comprises six pages and is understood as a general framework for environmental assessment, which can, however, be supplemented and specified by specific assessment frameworks for individual technologies. For example, the LP Parties have developed the "Ocean Fertilization Assessment Framework," which is approximately 40 pages long.

   Annex 5 includes the following sections for which information is to be provided by researchers.

- General description of the activity (this includes the above criteria for research projects).
- Description of the area of application (including physical, geological, chemical and biological and the gaps in knowledge)
- Explanation of the material to be applied (including origin, properties, contaminants, persistence)
- Assessment of the potential environmental impact
- Determination of risk management measures
- Determination of the monitoring measures
- Determination of the condition for approvability
- Reporting and evaluation obligations

   The value of these requirements is that they allow for a structured, measurable, and verifiable assessment of the expected environmental impacts.

4. The Amendment provides important procedural requirements. There are three main elements involved. First, potentially affected states must be consulted if a project may have effects in their EEZ or on the high seas. This obligation also applies to regional agreements represented by their organs. Furthermore, affected parties are to be consulted, in advance by the researchers themselves, after submission of the application by the respective competent authority. Furthermore, the competent authority may request an assessment by "independent international experts". Potentially affected states can request this.

On the one hand, these procedural regulations ensure that all potentially affected parties—be they individuals, states or regional agreements—can present their concerns and views in the licensing procedure and, in particular, before a decision is made. The possible involvement of international independent experts is a mechanism that ensures objectivity and transparency and can thus also contribute to conflict resolution. Furthermore, it enables states which do not have the expertise "in house" to rely on these experts.

5. According to Art. 6bis of the amendment, research projects require approval by the national competent authority, which must ensure compliance with the substantive requirements as well as the procedural regulations.

Through the regulatory concept according to the LP Amendment, all of the above-mentioned reasons for the necessity of controlling research, in particular field experiments, are addressed—at least indirectly. The criteria for determining whether a project is legitimate research, make it possible to "prohibit" projects that are either not legitimate research or that are not in the public interest and/or that pursue other goals. This is because the criteria basically require that the research project meets the standards of good scientific practice and is therefore not significantly influenced by economic or other interests. The obligation to publish the results contributes to transparency and the progress in scientific knowledge. In particular, also negative outcomes need to be made publicly accessible. This is of such eminent importance for society to get evidence-based information on the effectiveness of each technique to mitigate climate change and that there are no unacceptable risks for society and the environment. Some argue that LP considers only the risks, and does not take into account the potential benefits of Climate Engineering techniques (e.g., Webb, 2024)[7]. In fact, while the core mandate of LC/LP is the protection of the ocean, the parties to the London Convention and London Protocol have in fact recognized the importance of enabling further research into ocean CDR, but limit this to "legitimate scientific research". The purpose of this regulatory approach is to ensure society gets the most reliable and unbiased information needed to make decisions concerning the potential benefits and risks of marine CDR techniques. This information is aimed at enabling decision-makers to make well-informed decisions on marine CDR techniques, inter alia additional funding, prohibitions or allowing deployment, under certain prerequisites.

Concerning privately funded research, the fourth criteria is of particular importance. It reads: economic interests do not influence the design, conduct and/or outcomes of the proposed activity. "There should not be any financial and/or economic gain arising directly from the experiment or its outcomes. This does

7 See as one example "International Governance of Ocean-Based Carbon Dioxide Removal: Recent Developments and Future Directions" by Romany M. Webb (https://scholarship.law.columbia.edu/sabin_climate_change/216/).

not preclude payment for services rendered in support of the experiment or future financial impacts of patented technology." There are three main requirements: Economic interests should not influence the projects. Second: No direct financial gains should be received based on the outcomes of the projects. Thus, selling carbon credits would be not in line with this requirement. Third, however, payment for services are not precluded. These criteria intend to ensure that economic or financial interests or benefits are not undermining the high-quality of the research.

The structured environmental assessment according to Annex 5 serves to avoid negative effects as far as possible and allows to stop projects with unacceptable risks to be undertaken. These two checks—being legitimate scientific research and not having unacceptable risks—allow that financial resources—including those of the public sector—are essentially used for "meaningful" research projects.

The procedural requirements and the requirement for approval by a state authority ensure that all concerns are seriously examined and considered. It also ensures that affected parties can voice their concerns and review the appropriateness of the state's decision. In that sense, the procedural requirements work toward trust-building and strengthening international cooperation.

The two checks in combination with the consultation requirements also enable societies—in fact their legitimate representatives—to take evidence-based decisions and to invest the limited resources—financial and personal—reasonably.

The regulatory approach is thus innovative and appropriate, as it addresses in principle most of the concerns of effective governance of CE research projects. It is therefore a reasonable regulatory approach for climate engineering techniques other than ocean fertilization as well.

Here we argue primarily for the applicability of the LP regulatory concept to other marine geo-engineering techniques and to solar radiation management techniques, as far as field trials are not banned as it is discussed for stratospheric aerosol injections. Concerning terrestrial climate engineering techniques, the applicability depends first on the status of development and secondly on the envisaged scale of "deployment" and thus thinkable risks of the techniques.

General obligation under international law to apply the LP standard

An obligation to apply the LP regulatory approach—with the five elements mentioned above—to other climate engineering techniques cannot be—so far—derived from individual treaties and hence does not yet arise from international law. Neither the Convention on Biological Diversity nor the Montreal Protocol on Ozone Depletion under the United Nations Framework Convention on Climate Change (UNFCCC) contain comparable regulatory approaches.

Customary international law, i.e., the law between states that has developed over time through common practice combined with the will to make specific "obligations" legally binding, does require an environmental impact assessment and consultation with the affected states if circumstances are transboundary. However, the precise content of these obligations is not clearly defined. Therefore, no obligation to apply the LP approach can be derived from international customary international law. Also, this standard has not yet been recognized as "best practices", so that no obligation arises in this respect either.

Possible mechanisms for a more widespread application of LP standards

Therefore, the question arises whether and how it could be achieved that the LP regulatory approach for field trials is also applied to all other climate engineering techniques. In this respect, a distinction must be made between, firstly, international and national approaches and, secondly, legally binding and non-binding but equally effective mechanisms. The following provides only a rough overview and should be considered as food for thought.

It should be noted at the outset that in each case a corresponding political will of responsible actors would be required. If so, there are many mechanisms, each with advantages and disadvantages.

On the international level, the following legally binding solutions are generally available.

- Option 1: Listing of further (marine) climate engineering techniques in LP Annex 4 in connection with sufficient ratifications and/or the provisional application of the amendment
- Option 2: Amendment of the Montreal Protocol (ozone layer depletion) for SRM techniques involving stratospheric aerosol injection

In both cases, only one subset of Climate Engineering measures—in option 1: MGE techniques and in in option 2: SAI techniques—would be regulated at a time.

Furthermore, a Climate Engineering related protocol could be adopted under CBD or the Framework Convention on Climate Change. These could then apply to all techniques, including terrestrial ones, if appropriate, as far as field experiments should not be prohibited in principle (possible example SAI). Moreover, a stand-alone treaty on Climate Engineering would be an option as well as a regulation under UNFCCC.

Legally non-binding options at the international level would be, for example, a decision by the General Assembly of the United Nations or by the Parties to the CBD or the Framework Convention on Climate Change. As mentioned, depending on the international reputation of the body, the political and steering effect could be very effective.

At the national level, this approach could be introduced through national or domestic legislation. First, this could be regulated by sectoral provisions or in a comprehensive federal law. Second, one could also consider establishing compliance with LP requirements as a prerequisite for public funding. This would have the disadvantage that research funding agencies would also have to decide on environmental and health issues. If necessary, however, this disadvantage could be remedied by

cleverly structured participation process involving all relevant public authorities including environmental authorities. In any case, this would mean that funding agencies would exercise administrative power which would raise a lot of political concerns. Furthermore, such a procedure would not immediately apply to privately funded research.

There are thus possible pathways to apply the regulatory concept of LP to research projects for all climate engineering techniques—at least those funded publicly. Appropriate mechanisms exist at both the international and national levels, and it should be emphasized that international solutions have the advantage creating a level playing field for all—at least all those who have signed or supported the international agreement. Also, *in situ* experiments can be envisaged that involve partners from different countries and different national or multinational funding agencies. All options have pros and cons which cannot be discussed here in depth. In addition, it seems to be premature as, politically speaking, first a political will is needed to use the regulatory concept of LP for other climate engineering techniques.

Conclusions

A commitment for a legitimized regulation of climate engineering field experiments in the interest of the public good would be a considerable step forward compared to the current situation. Up to now, especially with regard to many marine CDR techniques, but also SRM techniques, it has not been clarified in which form research projects should and can be regulated and supervised. In this respect, there is a lack of agreements at the international level.

By applying the regulatory regime established under the LP, the following effects in particular would be achieved:

- By the criteria for differentiating research from deployment and by the environmental assessment, a transparent, objectified, reliable and verifiable assessment and control mechanism could be established.
- The procedural requirements—such as the obligation to consult and involve independent experts, as well as the approval requirement—would ensure transparency, accountability and informed decisions, which, in general, would also contribute to higher acceptance of the decisions.

As a result, this regulatory concept of LP can ensure that only high quality and responsible research is undertaken and reliable scientific knowledge will be available in time to underpin the upcoming societal and political decisions required to decide on the "suitability" of climate engineering techniques. In that sense the regulatory concept of LP is recommended for governing most geo-engineering techniques.

The political question of banning field trials for some techniques, such as stratospheric aerosol injection, would still need to be discussed.

Nevertheless, some questions remained unanswered: One aspect is that research is not necessarily an end in itself. Under German constitutional law, freedom of research applies, but this "freedom" is not unlimited. Consideration should be given to how to proceed if, after a number of research projects, there is considerable certainty that a technology cannot contribute to climate protection because, for example, the theoretical assumptions have proved to be inaccurate. Should (field) research then be discontinued—even against the background that research findings are never absolutely and eternally valid, but can always be questioned and refined? Or should just the public funding be ended?

Another aspect is the funding of research by private entities such as companies and foundations. The regulatory approach of LP can also be applied here, but a control of the research content is then possible only indirectly. Is there a need for government access to this private research funding in order to ensure that research serves the public good in the best way possible?

These questions will need to be answered elsewhere. Applying the LP regulatory approach to all climate engineering techniques would in itself be a major step toward responsible research in the interest of all.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

HG: Conceptualization, Writing – original draft, Writing – review & editing. AO: Writing – original draft, Writing – review & editing.

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