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Geoengineering governance-by-default: an Earth System Governance perspective

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Abstract:

Geoengineering—the deliberate interference in the climate system to affect global warming—could have significant global environmental and social implications. How to shape formal geoengineering governance mechanisms is an issue of debate. This paper describes and analyses the geoengineering governance landscape that has developed in the absence of explicit geoengineering regulation. An Earth Systems Governance perspective provides insight into the formation of norms resulting from an overlap in international treaties and from the actions of engaged non-state agents. Specifically, the paper explores the instruments and actors having effect in existing formal and informal geoengineering governance mechanisms. It finds that geoengineering is subject to a form of ‘governance-by-default’. This is due to a situation in which state actors have not resolved the tension between two legal norms: that of ‘caution’ and that of ‘harm minimisation’. This governance-by-default is characterised by uneven regulation from existing multilateral agreements established for other purposes, an absence of regulation specifically focused on geoengineering, guidance from an international ambition to hold global average warming below two-degrees Celsius and to achieve net-zero emissions in the second half of the century, and strong normative engagement by the research community. Governance-by-default is likely to be a stopgap development until more enduring and focused governance emerges.

Keywords:

Climate change; climate engineering; solar radiation management; carbon dioxide removal; international law

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The authors declare no conflict of interest.

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1. Introduction

Current attempts to reduce greenhouse gas emissions remain insufficient to hold global average warming below 2° Celsius above pre-industrial levels (Le Quéré et al. 2015). Consequently other means of restraining warming, referred to as climate engineering or geoengineering, are being proposed (Crutzen 2006; Keith 2013). Advocates contend that such ideas should be developed as additional measures for the climate change policy toolbox

(Keith 2000) and interest from research communities is growing rapidly (Oldham et al. 2014). However, some geoengineering techniques and technologies raise concerns relating to their potential transnational environmental and social impacts (Robock 2008); ‘geoengineering could be a "cure worse than the disease"' (Schneider 1996, p. 299).

This paper presents an analysis of international geoengineering governance, informed by a survey of existing regulatory instruments and recent controversial geoengineering activities, and a qualitative evaluation of the governance landscape that has resulted. It evaluates the status quo of geoengineering governance, which has been described as a ‘patchwork’ of regulation provided by multilateral agreements designed for other purposes (Larson 2016). In this paper, we take environmental governance to be a complex web of governmental and non-governmental rules and norms that shape the behaviours of actors and organisations seeking to navigate environmental change (Biermann et al. 2010).

The paper sets its discussion of geoengineering in the broader context of Earth System Governance (ESG) (Biermann et al. 2010) by addressing three specific questions: (1) what existing governance instruments are relevant to geoengineering; (2) who are the principal actors currently engaged in geoengineering; (3) what are the features and likely outcomes of geoengineering governance?

The paper consists of five sections. Following a brief introduction to geoengineering technologies, governance issues and risks, and an overview of ESG, the second section presents the research framework. The third section reviews the geoengineering governance landscape; the fourth highlights the norms that define that governance landscape. The fifth section argues that a form of governance-by-default prevails, and explores the implications. The final section concludes and identifies future research needs.

1.1 Geoengineering technologies and risks

The Royal Society defines geoengineering as “...deliberate large-scale intervention in the Earth’s climate system, in order to moderate global warming” (Royal Society 2009, p. ix). Geoengineering methods or technologies are divided into two overarching types: Carbon Dioxide Removal (CDR), which aims to reduce atmospheric carbon dioxide levels, and Solar Radiation Management (SRM), which aims to reflect some of the sun’s heat away from the Earth.

CDR geoengineering techniques are intended to draw carbon dioxide from the atmosphere, but do not affect greenhouse gas emissions. Examples include large-scale reforestation, bioenergy with carbon capture and storage (BECCS), and machines that ‘suck’ carbon from the air. To have a long-term effect, many of these techniques rely on geological storage of the extracted carbon. Other examples include processes to enhance the ocean’s biological capacity to draw down and sequester carbon in the deeper ocean. These include ocean fertilisation using iron or other nutrients, mechanical promotion of circulation of deeper

nutrient-rich waters to the surface, and ocean liming to reduce ocean acidity and increase carbon removal (Lenton 2014).¹

SRM techniques are intended to limit warming by intercepting solar radiation before it reaches the Earth's surface. Proposed methods involve atmospheric measures such as injecting particles into the stratosphere to deflect sunlight or spraying salt particles into low-lying marine clouds to make them whiter and more reflective; terrestrial measures such as covering the ocean or deserts with reflective material; and space-based approaches such as placing sunshades or mirrors in orbit (Vaughan and Lenton 2011).

Modelling suggests that SRM could reduce the differences in climates caused by elevated greenhouse gas concentrations (IPCC 2013), although with regional variations (Kravitz et al. 2014). Should greenhouse gas concentrations reach dangerous levels, some SRM methods could, in theory, be deployed quickly to bring temperatures down—an important consideration for those communities and species most vulnerable to rising temperatures. CDR offers the capacity to deliver negative emissions, which climate models suggest will be necessary to hold global average temperatures within 2° Celsius in the absence of effective SRM (IPCC 2013).

Nonetheless, the science of many geoengineering methods is complex and uncertain. The deployment of global geoengineering methods, or the application of local geoengineering methods at a scale needed to have global effect, as well as regionally disparate impacts is likely to have potentially adverse climatic and/or environmental effects (National Research Council 2015a, 2015b). Associated potential environmental and human impacts, and their possible uneven regional distribution, suggest that any prospect of geoengineering warrants measured consideration and debate at multiple jurisdictional scales.

Many geoengineering techniques pose governance issues common to other transboundary environmental problems, including the ethical dilemmas and the challenge of achieving harmony among competing political institutions, worldviews and values that confront attempts to govern the global commons. However, geoengineering technologies also face distinctive issues, such as the problem of 'moral hazard' posed by these technologies possibly becoming distractions from efforts of global mitigation and adaptation (Reynolds 2014).

Reports from bodies such as the US National Research Council and the UK Royal Society, and various other scientific and technical papers, contend that further research may reduce uncertainty about potential impacts and pave the way for robust decision-making around deployment and governance (Keith and MacMartin 2015; National Research Council 2015a, 2015b; Royal Society 2009). Many legal scholars and social scientists argue that governance should be developed alongside or even before further research into implementation, because of the moral and justice issues that can arise from some geoengineering technologies, and the uneven distribution of risks (Brent et al. 2016; Lin 2015). Despite these concerns, no binding international laws currently in force explicitly regulate geoengineering, in part because '[n]o

¹ There is no consensus in the geoengineering literature whether large-scale biochar, which is plant-based charcoal used to increase soil carbon retention, or large-scale afforestation should also be included in the definition of CDR.

binding definition of climate engineering exists under international law' (Rickels et al. 2011, p. 104).

1.2 Earth System Governance

Geoengineering involves large-scale changes to the global climate and thus cannot be considered in isolation from associated changes in ecosystems and society. The research framework developed by Biermann et al. (2010) to consider ESG integrates research into natural and human processes with the study of regulatory and management systems. It is thus well suited to the interrogation of geoengineering governance and has therefore been used in this study.

To untangle the multiple elements of governance, the ESG framework defines specific analytical problem structures and cross-cutting themes. ESG is described as the “interrelated and increasingly integrated system of formal and informal rules, rule-making systems, and actor-networks at all levels of human society (from local to global) that are set up to steer societies towards preventing, mitigating, and adapting to global and local environmental change and, in particular, earth system transformation, within the normative context of sustainable development” (Biermann et al. 2010, p. 279). The terms ‘steer’ and ‘sustainable development’ imply that environmental governance is purposive, guided by the values and goals of sustainable development, widely accepted as first established by the Brundtland Report as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987) and since articulated practically in the United Nations’ Sustainable Development Goals (UN General Assembly 2015).

The ESG framework describes five focal points for analytical attention. The first focuses on types and systems of *governance architecture*, and the second on the roles of *agents or actors* at different levels in governing Earth systems. The third highlights the importance of the *systemic adaptiveness* of governance systems to the needs of environmental change. The fourth focuses on the extent and means of *accountability and legitimacy* (of and) for governance mechanisms. The fifth focuses on defining and addressing questions of fair *allocation and access* regarding benefits, risks, and responsibilities in environmental change. The framework also identifies four fundamental elements that help constitute these focal points: power, knowledge, norms, and scale (Biermann et al. 2010).

2. Method

This study proceeded in two steps. It first described geoengineering’s international governance landscape using the first two analytical focal points of the ESG framework – relating to international governance architecture, and actors (or agency). It primarily analysed the architecture of governance; consideration of the role of actors provided additional insight and context. It then used the concept of norms to explore the resulting governance landscape (Figure 1).

Of the five elements of the ESG framework, architecture and agency were chosen because they provide, by their natures, the means to identify and sketch the elements of a geoengineering governance landscape. Whereas accountability, adaptability, and allocation are measures of the features of governance or the governance problem, architecture and

actors can be regarded as pure concepts and irreducible system elements. Consideration of norms ahead of the other constitutive drivers proposed by the ESG approach comes from our view that normative considerations underpin and explicitly or implicitly guide the choices inherent in the three other elements (power, knowledge and scale).

2.1 Governance architecture

A range of concepts and theories may be deployed to describe and analyse the structures of international governance. For instance, structures of governance may be analysed using regime theory: regimes are commonly understood to be a cluster of “principles, norms, rules, and decision-making procedures around which actor expectations converge in a given issue-area” (Krasner 1983, p. 1), while a regime complex consists of multiple overlapping regimes governing an issue-area (Keohane and Victor 2011). By contrast, here we employ the concept of ‘governance architecture’ – or sometimes more succinctly, ‘architecture’ – to refer more narrowly to government-established frameworks or structures (Biermann et al. 2009; Pattberg et al. 2014) and to suggest an institutional framework deliberately designed and constructed (although this can be taken too far, as is discussed below in relation to agency). In other words, the concept is used here, analytically, to distinguish deliberate, formal and government-based mechanisms from informal and non-government ones.

The governance architecture of geoengineering was identified through a review of international agreements (treaties, conventions and their protocols) recorded in two key treaty databases: the United Nations Treaty Collection (UNTC) and the Environmental Treaties and Resource Indicators (ENTRI) database. Both were searched for the terms ‘environment’, ‘climate change’, ‘biodiversity’, ‘biological diversity’, ‘ocean’, ‘sea’, ‘atmosphere’, ‘air space’ and ‘outer space’—terms selected to reflect the land-based, oceanic, atmospheric, and space-based nature of geoengineering technologies and the arenas of their potential effects. The scope of the review was restricted to multilateral agreements with more than 50 members. While inclusion of bilateral or minilateral agreements would provide more detailed picture, it is believed not to offer a significantly different picture.

2.2 Actors and agency

A review of international treaties that focuses only on the outcomes and frameworks of governance formally agreed among states provides only an incomplete and somewhat static picture of geoengineering governance. Therefore, this study also examined the role of both state and non-state actors and agents relevant to international governance of geoengineering to provide additional depth and context the analysis.

Agency can be defined as the “capacity of individual and collective actors to change the course of events or the outcome of processes” (Pattberg and Stripple 2008, pp. 373–4) and agents can be described as those ‘authoritative actors’ who directly or indirectly influence the decisions of others (Dellas et al. 2011). In this study, we initially use a more expansive approach, by considering actors without necessarily attributing agency. The question of

whether these actors have become agents is addressed in the subsequent discussion of norms and governance.²

Here, actors were identified through their geoengineering governance-related actions, which include participation in:

- the production of publications (from academic articles to media statements) that frame the governance of geoengineering,
- the creation of key laws (including lobbying for, input into, drafting or passing of laws),
- involvement in key projects or experiments (both involvement in and oversight of),
- establishment of epistemic networks involved in discussions of geoengineering (through workshops, as collaborative ventures between individuals, communities or nations), and
- funding any of the above activities (with implicit or explicit decisions being made about the legitimacy of geoengineering).

Instances of these actions were collected from reviews of the geoengineering academic and grey literature and from media reports. Specifically, the terms ‘geoengineering’ and ‘climate engineering’ were used with keywords from the above list in a Google search and then a Web of Science search. Actors were categorised into seven groups: intergovernmental organisations (IGOs), States, academia, non-governmental organisations (NGOs), philanthropy, commercial interests, media, and ad hoc geoengineering groupings. The last category refers to networks of individuals that have formed specifically around geoengineering, but were not captured by the other categories.

2.3 Norms

This study also analysed the norms structuring this governance landscape. Norms are widely understood to be social standards that “channel and regularize behaviour...often limit[ing] the range of choice and constrain[ing] actions” (Finnemore and Sikkink 1998, p. 984). Such standards can be articulated formally through laws and regulations or through informal cultural mechanisms and related codes of practice. Norms formally deployed by states and relating to geoengineering were identified through an analysis of relevant international agreements. Norms developed and established by non-government players were identified by reviewing commonalities and deviances in actors’ behaviour.

Figure 1: The research framework and process

INSERT FIGURE 1 SOMEWHERE AROUND HERE

3. Elements of geoengineering governance

² As it is not clear where to draw the line in considering which actors become agents and which do not, Dellas et al. (2011) recommend cataloguing actors involved in an issue area and then clarifying which of those actors has become authoritative, highlighting that “the source of authority underpinning agency may be found in agents’ capacity to be more responsive and participatory than public institutions, in the unresponsiveness of state bureaucracies, in effective and efficient problem-solving and finally in their ability to gain the recognition of key audiences as innovative and successful problem-solvers” (2011, p. 93).

3.1 Architecture

The review of international agreements (treaties, conventions and their protocols) that might contribute to governance of geoengineering identified 11 principal instruments, most with related Protocols or Agreements or other treaties part of a collection of treaties (i.e. the Antarctic Treaty System (ATS) and the collection of outer space treaties (OSTs) are each counted as having one principal instrument) (Table 1).

INSERT TABLE 1 SOMEWHERE AROUND HERE

International legal scholars distinguish between ‘hard’ law, which is binding or enforceable, with clear obligations and delegations, and ‘soft’ law, which lacks some or all of these elements (Abbott and Snidal 2000; Chinkin 1989). No hard international law currently in force *explicitly* mentions geoengineering or a geoengineering technology (Bodle et al. 2014; Rickels et al. 2011). However, as Table 1 indicates, multiple multilateral agreements contain ‘hard’ and ‘soft’ law elements that contribute to the governance of geoengineering technologies.

Three treaties have sought to address geoengineering or a geoengineering technology directly, albeit not necessarily explicitly using those terms. The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD) treaty from 1978, which was designed with weather modification in mind, prohibits environmental modification for the purposes of warfare and therefore restricts geoengineering only if the act was hostile, destructive, and with widespread, long-lasting or severe effects (Bodansky 2011; Virgoe 2009).

The Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) passed a decision in 2010 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 (CBD COP decision X/33 8(w))

This has been interpreted by some commentators as a general moratorium on geoengineering (Tollefson 2010; Walsh 2010), but the legal status of the Convention and the language of the text fail to define any legal obligation (Scott 2012). The decision supports small-scale scientific research into geoengineering (CBD 2010). A subsequent CBD COP decision, in 2016, called for ‘more transdisciplinary research and sharing of knowledge among appropriate institutions’ (CBD 2016).

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Convention or LC) and its protocol (the London Protocol) (the LP) have provided a platform for legal debate regarding marine geoengineering. Amendments passed under the LP create an updateable list of marine geoengineering methods that can be either banned or limited to legitimate scientific research—currently only ocean fertilization is listed.

These amendments have not come into force (and are therefore in this study considered ‘soft’ law).

In total, three Conventions regulating oceans are relevant to geoengineering technologies with marine elements (Table 1). Two regulating the atmosphere are relevant to geoengineering technologies with atmospheric elements (although the Convention on Long Range Transboundary Air Pollution (CLRTAP) with a membership of 51 nations just met the criteria for inclusion). The outer space treaties regulate outer space and are relevant to space-based technologies. Another five Conventions are likely to apply broadly to many geoengineering technologies.

In its aim to reduce the effects of climate change, protect the environment and benefit humanity, geoengineering (or at least further research into geoengineering) appears to be *supported* by many of these instruments: the UN Convention on the Law of the Sea (UNCLOS), the CBD, the UN Convention to Combat Desertification, the OSTs, the ENMOD Convention, the United Nations Framework Convention on Climate Change (UNFCCC), the Vienna Convention and the ATS.

The UNFCCC and its 2015 Paris Agreement deserve special mention. The UNFCCC explicitly supports climate change policies that are least-cost and establishes that “lack of full scientific certainty should not be used as a reason for postponing such measures” (*UNFCCC* art 3). According to some scholars, this could support any geoengineering scheme that might be considered ‘least-cost’ (Virgoe 2009). The UNFCCC also urges all Parties to “promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs [...] including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems” (*UNFCCC* art 4(d)). This acknowledges the importance of conserving and enhancing biological sinks. The question is whether a definition is needed to distinguish CDR from other activities that enhance biological sinks to balance greenhouse gas emissions. It can be considered that BECCS, large-scale biochar and large-scale afforestation are all possible CDR measures and therefore Article 4 could be seen as supportive of those. The 2015 Paris Agreement establishes a goal of holding average global warming well below two-degrees Celsius and reaching net zero gigatonnes of emissions in the second half of the century. By urging its parties “to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse” (*Paris Agreement* art 4), it ostensibly supports geoengineering, including CDR and, potentially, indirectly, SRM.

All 11 treaties in some way restrict how or where geoengineering or specific technologies might be used. For example, the Paris Agreement emphasises the need to ensure that action is taken in a manner that “does not threaten food production” (*Paris Agreement* art 2). The outer space treaties emphasise that space-based SRM schemes would need to have “due regard” for other Parties to the Treaty (*Outer Space Treaty* Art IX), and liability would arise if it could be established that a space object caused damage to human health or property of a State (*Space Liability Convention* Art II) (Humphreys 2011; Rickels et al. 2011).

Finally, although not expressly noted in Table 1, geoengineering is also governed by customary international law, such as the no-harm rule and the duty of due diligence to prevent transboundary harm, of which a duty to conduct an environmental impact assessment is a component (Brent et al. 2015; Scott 2012).

3.2 Actors

International treaties provide only one, albeit very important, contribution to the architecture of international geoengineering governance. To contextualise this picture, here we look at the additional role of state and non-state actors.

Geoengineering governance has been expressly considered only in the United States (US), the United Kingdom (UK), and Germany. The European Union, a supranational entity, can be added to that list because it acts as a unified entity in many international fora. In Canada, Norway, Australia, Russia, China, and India, geoengineering has been recognised as an issue by some government bodies, but has not become a matter of national priority. No country has an official policy on geoengineering, nor has any government department been relegated responsibility.

Several governments have supported further research. For instance, in 2009, the German government supported an ocean fertilisation scientific research project in collaboration with Indian scientists, arguing that the experiment was small-scale and therefore did not conflict with international treaty decisions. No environmental impact assessment of the project was undertaken, despite such a requirement being included in many forms of ‘soft’ and ‘hard’ international law identified in the previous section. In 2012, an ocean fertilisation project was undertaken by a commercial entity off the coast of Canada, and has prompted the Canadian government to investigate the matter.

At the intergovernmental level, the UN General Assembly, the UN Educational, Scientific and Cultural Organization (UNESCO) and its Intergovernmental Oceanographic Commission (IOC), the Intergovernmental Panel on Climate Change (IPCC), and the World Meteorological Organisation are amongst the organisations that have shown some interest in geoengineering. A common feature of their positions is support for further research (especially collaboratively) and a precautionary view of ocean fertilisation.

Geoengineering debate and agenda-setting are strongly driven by academics, including natural scientists, engineers, legal scholars, economists, and philosophers, mostly from English-speaking Western countries, particularly in the Northern Hemisphere (Belter and Seidel 2013). These academics seem to have clustered into groups constituting and advocating different orientations for geoengineering governance. While all urge a focus on mitigation before consideration of geoengineering, some strongly support further research while others are more wary of this on ethical grounds. There are, nonetheless, a number of ongoing geoengineering experiments, both laboratory-based and field-based (Keith et al. 2014)

A limited but growing grey literature (mainly emanating from multi-disciplinary academic discussions) adds to this academic work. For example, the Oxford Principles – a group of proposed guiding principles for geoengineering governance produced by a group of academics (Rayner et al. 2013) – have been influential among academics, NGOs, intergovernmental and state actors (Asilomar Scientific Organizing Committee 2010; CBD Secretariat 2012; iagp.ac.uk 2015; NERC 2016). For instance, one outdoor SRM experiment, known as the Stratospheric Particle Injection for Climate Engineering (SPICE) project, was designed to investigate engineering feasibility of stratospheric aerosol injection and included a trial of pumping water through a pipe kept aloft by tethered balloons (Cressey 2012). The

field trial was ultimately abandoned, with the leader of the SPICE project citing the Oxford Principles in justifying his group's decision to cancel the experiment (Watson 2012).

Although NGO interest in geoengineering is limited (Nicholson and Thompson 2015), Rickels et al. 2011) and lacks cohesion, large transnational NGOs have been important in terms of agenda-setting. For instance, Greenpeace International and the World Conservation Union were instrumental in raising marine geoengineering onto the LC/LP agenda (Greenpeace International 2007; IUCN 2007).

Some non-negligible funds have been disbursed by philanthropists to further geoengineering research. There has been little commercial interest other than a limited number of patent applications, and here commercial interest has been in CDR only. One American entrepreneur, Russ George, through a series of ocean fertilisation projects, is responsible for triggering debate over geoengineering at the international level (through the LC/LP) and at the state-level (Canadian investigation into the ocean fertilisation project incident).³

4. The role of norms in international geoengineering governance

By what norms is geoengineering governed? Two types of norms are considered here: legal and social.⁴

4.1 Legal norms

Legal norms are those based in laws (and associated regulations) that encourage or require, or discourage, certain behaviours. We confine our attention to legal norms that manifest in the international treaties listed in Table 1. Analysis of national laws is beyond the scope of this study, but would add value as national laws implementing international treaties provide additional indications of the effectiveness of a legal norm.

Two overarching legal norms can be distinguished. The first is that of 'precaution'. Without delving into the complex and ongoing debate on the various forms and meanings of the precaution principle (of which there are many (Elliott 2010)), we define this norm as requiring inaction until potential significant dangers and consequences are better understood (while recognising that the principle also encourages beneficial action even if scientific knowledge about outcomes is incomplete). In the case of geoengineering, at present this

³ There is another discussion to be had about the informal influence of actors at the national level. The public debate around geoengineering is heterogeneous and complex, as evidenced through different media portrayals and the perspectives underlying popular literature. Networks of highly active conspiracy theorists have developed. A survey of 3000 individuals across the US, Canada and the UK found that 2.6% of those questioned completely believe that there are covert government activities spraying atmospheric contaminants and 14% partly believe it (Mercer et al. 2011). Anecdotal evidence suggests that many individuals who believe in these 'chemtrail' conspiracies attend academic conferences, and there are reports of such people having abused and threatened geoengineering researchers (Cairns 2014). The views of these groups were noted by the US Congress during committee hearings on geoengineering (*House Hearing 111 Congress* 2010).

⁴ Moral norms are not considered here, as this would require insight into actors' convictions, which may not be reflected by their actions.

principle disallows or discourages the deployment of potentially significant and irreversibly harmful technologies or techniques, certainly in the absence of guidance from and limitation by relevant laws.

This is evidenced in the soft law of the LC/LP 2008 resolution that no ocean fertilisation take place until “a global, transparent and effective control and regulatory mechanism is in place for these activities” (LC/LP 2008), and that of the CBD COP decision calling for no geoengineering activities with potential biodiversity impacts to take place “in the absence of science based, global, transparent and effective control and regulatory mechanisms” (CBD COP 2010, para. 8(w)).

The second legal norm is that of ‘harm minimisation’. Many of the treaties in Table 1 include environmental and social safeguard clauses, and these concepts are also enacted through common and customary law. For instance, CBD decision in 2010 require that research include “prior assessment of the potential impacts on the environment” (Convention on Biological Diversity 2010, para. 8(w)), while the adopted (but not in force) LP amendment resolution LP.4(8) outlines six pages of an assessment framework that must be followed before legitimate scientific research into ocean fertilisation may be considered (LC/LP 2013). ‘Harm minimisation’ drives decisions and actions, and supports research, that are in aid of preserving the environment and of benefiting mankind. In relation to geoengineering, which aims to reduce the harms associated with climate change, it legitimises research. The decisions of both the LC/LP and the CBD deliberately exclude “small scale scientific research” from their restrictive rulings (CBD COP 2010; LC/LP 2008). This norm is also overarchingly (although implicitly) articulated by the UNFCCC’s Paris Agreement, which confirms a 2° Celsius warming limit and establishes the goal of reaching net zero gigatonnes of emissions in the second half of the century – the ‘2C&0Gt’ target.

Legal norms are effective inasmuch as they are legitimately enforceable and enforced, yet enforcement mechanisms of international law are limited. As a result, not all legal norms are fully observed. The precautionary principle here serves as a norm requiring inaction until consequences are better understood. It is difficult to observe conformity to a norm when this is expressed through inaction, but the effect of the norm can be observed in states’ responses (if any) to cases of nonconformity. So, for example, how the Canadian Government has responded to the 2012 ocean fertilisation project off the coast of British Columbia is a test of the depth and strength of international support for this norm. Although there was discussion of the experiment at subsequent meetings of the CBD, there is no evidence that other states heavily condemned the experiment or have pressured the Canadian government to react in any specific way. It would thus be premature to assert whether this norm has a strong element of enforceable obligation. By contrast, the second norm – ‘harm minimisation’ – is a norm that emphasises beneficial action, such as for example, active research agendas.

These two norms’ relationship to each other is not straightforward. The precautionary principle prohibits both taking action without sufficient insight into the consequences, and using the excuse of insufficient scientific understanding for inaction where action might be beneficial. In contrast, harm minimisation requires action. Under conditions of relative certainty both can be complementary in that one cannot proceed to minimise some harm while causing more than is minimised. However, while there is uncertainty on the impacts of

both action and inaction, the relationship between the two can seem contradictory: one enables while the other disables.

The tension between the two can be resolved if research and deployment can be cleanly separated. 'Precaution' defers deployment until rigorous research can assure us that 'harm minimisation' is the dominant outcome. Yet research and deployment cannot be clearly divorced from each other for some geoengineering technologies, either physically or from a governance perspective. Where geoengineering methods are intended for non-encapsulated systems, such as the ocean or the atmosphere, testing, monitoring and data collection need to take place over a large area and a long term, maybe a decade (Robock et al. 2010), for detection and attribution of the effects of experimental inputs against the background of other natural variations. For these techniques, some types of fieldwork could be safely undertaken (such as small-scale experiments designed to explore limited and bounded hypotheses), but often there is no clear line between meaningful field-testing of geoengineering and deployment (Keith et al. 2010). There is also the potential for a financial or technological slippery slope from research to deployment (Oldham et al. 2014).

4.2 Social norms

Social norms are cultural codes that define what is considered to be acceptable behaviour and what is considered to go against that standard (Finnemore and Sikkink 1998). While social norms may find 'hard' forms of expression (in formal, state-sanctioned laws and rules), here we will concentrate on 'soft' or more informal codes and practices. Actors within a reference group could establish and conform to a social norm for different individual reasons. Therefore, in this study we do not delve into actors' expectations or beliefs, we limit the study to observations of behaviour.

Intergovernmental organisations, through their reviews and publications, play both norm- and agenda-setting roles. The increasing number of wide-ranging and comprehensive publications from these organisations normalises geoengineering research that is both collaborative and publicly available, while the conclusions and key messages of these reports establish the ongoing agenda. The key messages from these reports are that the science behind many of the more controversial geoengineering proposals is highly uncertain and that ocean fertilisation is likely inefficient and risky (see for example IPCC 2013; Wallace et al. 2010).

A limited number of governments is involved in any discussion of geoengineering and there is a lack of regulation and discussion of the topic from even those nations. However, both the US and the UK have urged international bodies to consider regulating geoengineering (DECC 2010; US 2007) and those states that have been in any way involved with discussing geoengineering have mostly supported or funded further research. The actions of state actors suggest that governments have not been able to resolve the tension between the legal norms of 'precaution' and 'harm minimisation'. This results in state actors being either disengaged or adopting a 'wait and see' response while supporting further academic research in the context of the '2C&0Gt' target.

Academia cannot be described as one homogenous community, and it is difficult to discern consistent behaviour throughout the geoengineering research literature. Nonetheless, one recurring theme among many academics is an emphasis on self-regulation. Some scholars explain that self-regulation fills the void from a lack of top-down regulation (Rayner et al.

2013). Examples of self-regulation can be found in a number of academic articles as well as in the outcomes of the Asilomar II conference and in the creation of the Oxford Principles. The Oxford Principles are explored further here because, having been specifically referred to by IGOs, national governments, NGOs and others, they are potentially indicative of norm-setting.

The first Oxford Principle—geoengineering to be regulated as a public good—explicates the importance of public funding for research. To date, most geoengineering research funding has been provided by public sources, although philanthropy has played a small role. The existence of patent applications contributed to the decision by the SPICE project leader to cancel the field trial. The actions of Russ George, who has undertaken geoengineering activities with commercial intent, are considered deviant behaviour by the academic community (Lin 2015), confirming the existence of a standard within that community.

The second principle—public participation in geoengineering decision-making—includes stakeholders whose cultural beliefs may be challenged by the concept of geoengineering. Accordingly, many academic projects have sought input from the public and from local stakeholders. For instance, a public engagement exercise was established for the SPICE project despite the project's physical risks being minor (Pidgeon et al. 2013). Even so, a number of ocean fertilisation projects have taken place without broad stakeholder consultation (Williamson et al. 2012).

The third principle—disclosure of geoengineering research and open publication of results—aims for accountability and legitimacy, which are also emphasised in the ESG approach. However much of the academic literature is published in restricted-access journals and often is written in technical jargon. It is arguable that this third principle can be considered an accepted standard within the academic community.

The fourth principle—independent assessment of impacts—includes assessments of “environmental and socio-economic impacts of research, including mitigating the risks of lock-in to particular technologies or creation of vested interests” (Rayner et al. 2013, p. 507). This type of oversight has not been evidenced in academia or external groups. Although there have been some proposals on how to implement this concept, no such culture seems to have developed beyond the usual practice of scepticism that drives the scientific community to question new findings before these become generally accepted.

The fifth principle is governance before deployment. Although there is consensus on this principle from academic communities, the principle is problematic and again emblematic of the difficulty in navigating the contradiction between ‘precaution’ and ‘harm minimisation’. As the authors of the Oxford Principles concede, the boundary between research and deployment of geoengineering can for some techniques be “fuzzy” (Rayner et al. 2013, p. 507), yet the principle inherently assumes that it is not.

The key standards to which the academic geoengineering community aspires are thus public participation, accountability and transparency. To some extent these are met, for example, funding is largely from public bodies and there are clear attempts at deliberation and transparency from research groups. However, there are still questions around how far deliberation and participation should reach and to what level of transparency is needed. These

issues likely stem from the difficulty in distinguishing between deployment and research. Self-regulation is an attempt to manage this.

Finally, as noted, NGOs have had mixed responses to geoengineering, although a call for further research is increasingly common. Some NGOs have filled important agenda-setting roles by bringing geoengineering to the attention of national or international agencies, and the NGO-driven Solar Radiation Management Governance Initiative has begun a process of engagement with developing countries, but more broadly NGOs have not yet fully engaged with geoengineering and may be adopting ‘wait and see’ stance at this stage.

5. The geoengineering governance landscape

The above analysis shows that geoengineering is loosely governed in an unplanned manner by a mix of international agreements designed for other purposes. There is a regulatory standstill evidenced by the reticence of states to create laws around geoengineering at the national level. Although some countries have engaged in geoengineering discussions and provided public funding for research, this has been uncoordinated and unevenly distributed (Armeni and Redgwell 2015a; Bracmort and Lattanzio 2013). National governments seem hesitant to consider national geoengineering rulings, calling instead for increased geoengineering research and endorsing academic self-regulation through the Oxford Principles (Armeni and Redgwell 2015b, 2015a). As a result, international governance has not progressed. There is a push from many directions to increase scientific knowledge and reduce uncertainties, putting the focus on the research community.

In their bibliometric study of geoengineering research, Oldham et al. (2014) sought to highlight evolving trends in academic literature and in patenting asserting that “[i]n the absence of an established governance framework, the practices of scientific research and intellectual property tend to shape the field and set trajectories for future development” (2014, p.2). Their analysis built on an emerging literature on research governance that positions scientists and academics as *de facto* governors, whose values, commitments, and actions effectively limit or prejudice the range of technology options available in the future, thereby shaping the development of that technology.

Our study looks beyond the narrow research community and suggests a different (although complementary) perspective to that of *de facto* governance. The term ‘de facto’ means ‘of fact’, something that is occurring (or has occurred) whether or not expressly prescribed. Certainly, scientists in the geoengineering research field are able to dictate, decide and determine a number of factors that shape what is being researched and how. This can lead to one technology or technology-type gaining momentum, while another is disregarded for reasons that may not accurately reflect the needs or wants of societies. It can also lead to certain worldviews or framings dominating the research agenda. However, a study of norms suggests that a top-down legal norm of harm minimisation already frames that research agenda and constrains it to within the ‘2C&0Gt’ target area. The ‘2C&0Gt’ target essentially establishes and defines the problem that is to be solved. Thus, in summary, *de facto* governance expresses the ability of the research community to steer the research agenda of emerging technologies by establishing programs, networks and institutions that set the evolution of those technologies within the ‘2C&0Gt’ target.

Rather than *de facto* governance, here, we find that geoengineering is in a state of ‘governance-by-default’, with the term ‘by-default’ meaning ‘for lack of opposition’. That is, academics are acting to the full extent of their capacities, and potentially beyond, for lack of any barriers, within and beyond the research arena. The characteristics that define this ‘governance-by-default’ are an absence of purposive regulation, an existing driver (here, the ‘2C&0Gt’ target as established by a norm of harm minimisation), a propensity for regulators to postpone decision-making (here, in anticipation of improved scientific certainty to resolve the tension between precaution and harm minimisation), engagement dominated by one actor-group (here, academia), and ultimately a blurring of the lines between the different roles of societal players (here, related to the difficulty in separating research from deployment). Scientists have taken on the responsibility of self-regulation and begun to stray into a broader role of governance by advocating terms of deployment, not just research.

De facto governance of the research agenda is a part of the concept of geoengineering governance-by-default, but it is only one element. Governance-by-default is a broader concept. It encompasses also the values associated with geoengineering, and its treatment by the non-academic community. Through such initiatives as the Oxford Principles and other attempts at self-regulation, the research community seeks to anticipate and to respond to concerns of societies thus shaping more than just the research agenda. Against the backdrop of passive governments and NGOs, the actions of the research community are amplified. Returning to the distinction between actors and agents, it can be argued that the research community, by being more responsive to, and participatory in, issues of geoengineering than public institutions, have been conferred legitimate authority. These actors thus become lead agents in geoengineering governance until other authorities become engaged.

Governance-by-default is likely a transitory form of governance, existing only until discernible and effective forms of deliberation emerge or a crisis arises. In the case of geoengineering, it may evolve as a learning-by-doing governance related directly to the management of individual technologies. For example, a series of ocean fertilisation trials triggered debate amongst NGOs, IGOs and some governments and resulted in the development of restrictive governance measures within the CBD and LC/LP. These could eventually form the basis of broader geoengineering governance. As cloud brightening, stratospheric aerosols, or another technology reach sufficient scientific maturity, interests in or against these technologies are likely to develop. The boundaries between these interests of different actors may define the next formative stages of geoengineering governance.

This type of governance has emerged because governments have adopted a ‘wait and see’ approach as a reaction to the contradiction of enabling research while disabling deployment when there are only soft barriers between the two. A ‘wait and see’ approach allows governments and regulators to ensure that governance matches the realities of the technologies. Yet, this assumes that further research will reduce uncertainties sufficiently to allow control of environmental outcomes and to provide a basis for regulation. This ignores that, under a governance-by-default situation, researchers already influence prospective regulation. The definition of ESG establishes that governance of environmental transitions occur in a purposeful manner (steered) and in consideration of the needs of future generations (sustainable development). It can be argued that geoengineering governance-by-default does have an element of steering—the direction is set by the level and type of engagement from

various actor groups on a reactive basis. It is being steered by the ‘2C&0Gt’ target, by scientists’ interpretation of that target and by the isolated actions of NGOs, IGOs and individuals in response to the science. However, it is difficult to argue that this steering has an end-goal or clear purpose within the context of sustainable development. Although the ‘2C&0Gt’ target and legal norms of harm minimisation align with sustainability values, governance-by-default is reactive; it offers no coordinated proactive management of emerging issues. As a result, it could ignore potential threats and opportunities that may emerge for future generations, unlike anticipatory governance, which values reflexivity and foresight (Guston 2014).

6. Conclusion

Geoengineering could contribute to the climate change problem in either a remedial or antagonistic manner, depending on how it is managed. A proactive approach to the future of geoengineering governance is needed to avoid the negative outcomes and promote optimal outcomes for all. Having examined how geoengineering is governed, this paper concurs with Larson (2016), finding that international agreements mostly provide only unplanned and piecemeal governance over geoengineering at the global scale. Its analysis also establishes that this lack of direct and intentional governance extends to the national level, where it seems that governments are reticent to provide clear guidance on geoengineering. In the absence of an explicit international effort to govern geoengineering towards any agreed outcome, one cannot refer to a fully articulated geoengineering regime at this stage. Instead, we find a form of governance-by-default that is not guided by an overarching strategy.

This type of governance has emerged because, while one group of actors (academic researchers) is responding actively, governments plus other actors have adopted a ‘watching brief’ on the issue, due to an inability to reconcile two conflicting legal norms: that of precaution, and that of harm minimisation. Governance-by-default of geoengineering will persist until the ‘watching brief’ of governments (or other actor groups such as NGOs) comes to an end and a regime transpires.

Nonetheless, it could have permanent effects on enduring governance. It defines the formation of interest groups, especially those opposed to individual geoengineering technologies, and sets the issues of concern on an *ad hoc* basis. It also enables the *de facto* governance role of academics. By submitting such high-stakes technologies to scientific inertia, governments risk losing the ability to intervene in the fate of these technologies. In this study, we have not explored the ESG concepts of scale, knowledge and power, but these elements are clearly relevant in the context of governance-by-default and warrant further analysis. Similarly, the prevalence of certain actor groups as key agents of geoengineering governance raises issues of accountability and legitimacy that merit additional consideration.

Some scholars have argued that adaptive governance is required to respond to changing knowledge and societal norms relating to geoengineering and to help shape them (Payne et al. 2015). Instead, our study suggests the need for anticipatory governance, which also prioritises public participation, deliberation and adaptive management, but emphasises the need for foresight as an overarching framework. To transition governance-by-default to a more enduring solution within the context of sustainable development, forward-looking engagement that elucidates possible future scenarios of geoengineering deployment and

governance is needed from all nations, including those that have not engaged in the debate thus far. Informed, interdisciplinary and deliberative research could help structure purposive governance of geoengineering, and ensure that knowledge production embraces a broad range of views and interests.

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Table for “Geoengineering governance-by-default: an Earth System Governance perspective”

Table 1: International legal instruments relevant to geoengineering

Instrument (Membership)	Treaty’s main objective	Articles, protocols or amendments of potential relevance to geoengineering	Technologies of potential relevance
UN Convention on the Law of the Sea (UNCLOS) (168 parties - does not include the US)	Establishes the legal framework for allocating, protecting and preserving the marine environment.	Countries with coastal areas have jurisdiction over their maritime zone and the airspace above it. To conduct an activity in another country’s internal or territorial waters requires consent (Redgwell 2011; Rickels et al. 2011). Environmental impact assessment is required for potentially risky projects.	Ocean fertilisation; ocean liming; CCS; up- or down-welling; cloud brightening from ships
Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention) (87 parties - includes the EU, the US, Canada, Russia and China)	Regulates activities that may constitute ocean pollution	<p>The London Protocol to the London Convention (LC/LP), which has 47 parties (and does not include the US or Russia), has passed resolutions relating to ocean fertilisation. A 2008 resolution was passed stating that “<i>ocean fertilization activities other than legitimate scientific research ... should be considered as contrary to the aims of the Convention and Protocol and not currently qualify for any exemption from the definition of dumping</i>” (LC/LP 2008)</p> <p>A 2010 resolution provides guidance to Parties on assessing ocean fertilization research proposals and for completing an environmental assessment with risk management and monitoring (LC/LP 2010).</p> <p>An LC/LP amendment regulates marine geoengineering activities and adds two new annexes: a list of regulated marine geoengineering activities (currently only ocean fertilisation is listed), and an assessment framework to define legitimate scientific research (LC/LP 2013). (the amendment has been adopted but is not in force)</p>	Ocean fertilisation
International Convention for the Prevention of Pollution from Ships and Protocol (MARPOL 73/78) (155 parties)	Aim to eliminate marine pollution and accidental spillage of oil and other harmful substances resulting from ships.	Within certain specially designated protected areas, the Convention and its Protocol limit discharge into the sea of hazardous substances (Bodle et al. 2014).	Ocean fertilization; ocean liming
Convention on Long Range Transboundary Air Pollution (CLRTAP) (51 parties -does not include China)	Limits transboundary air pollution.	<p>The Convention itself limits emissions of substances that “<i>result in deleterious effects</i>”.</p> <p>The protocols list certain substances. Three protocols establish quantified limits for sulfur emissions (but these protocols have fewer than 30 signatories) (Rickels et al. 2011).</p>	Stratospheric aerosol injection; cloud brightening Stratospheric aerosol injection

Instrument (Membership)	Treaty's main objective	Articles, protocols or amendments of potential relevance to geoengineering	Technologies of potential relevance
Vienna Convention on the Protection of the Ozone Layer (196 parties - includes the US)	Establishes a legal framework for protecting the ozone layer.	The Convention sets out general obligation for Parties to “protect human health and the environment against adverse effects [...] from human activities which modify or are likely to modify the ozone layer” (Vienna Convention art II)	Stratospheric aerosol injection; cloud brightening
United Nations Framework Convention on Climate Change (UNFCCC) (197 parties - includes the US)	Establishes a legal framework for manage a global climate change response.	The treaty's ultimate objective is stabilization of atmospheric greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system. Article 4(d) urges all Parties to “promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs [...] including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems” (UNFCCC art 4(d)). Also, the Paris Agreement to the UNFCCC establishes an aim “to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse” (Paris Agreement art 4).	CDR
		The Paris Agreement defines a goal of staying well below two degrees, and aiming for 1.5 degrees. However, it emphasises the need to ensure that action is taken in a manner that “does not threaten food production” for example (Paris Agreement art 2), and that it is achieved on “the basis of equity, and in the context of sustainable development” (Paris Agreement art 4).	SRM
Convention on Biological Diversity (CBD) (196 parties - does not include the US)	Aims for the conservation and sustainable use of biological diversity with fair and equitable sharing of the benefits arising out of such resource use.	The Convention itself cautions against activities that threaten biodiversity and promotes activities that conserve biodiversity. The Conference of the Parties (COP) has adopted three decisions that relate to geoengineering. In 2008, the COP cautioned precautionary behaviour with regard to ocean fertilisation (CBD COP 2008). In 2010, the COP invited Parties to ensure that no geoengineering activities with potential biodiversity impacts take place “in the absence of science based, global, transparent and effective control and regulatory mechanisms”, but “with the exception of small scale scientific research studies” (CBD COP 2010, para. 8 (w)). In 2012, the COP invited Parties to address climate engineering research gaps (CBD COP 2012). The scientific advisory body of the CBD COP (the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA)) was instructed to undertake a three studies relating to geoengineering. The SBSTTA produced three reviews: one on the science and impacts, one on the legal framework, and one on the view of indigenous and local communities (CBD SBSTTA 2012a, 2012b, 2012c). The latter involved meetings and electronic discussions with relevant stakeholders, and was conducted with assistance from UNESCO, the UN Permanent Forum on Indigenous Issues and the Office of the High Commissioner on Human Rights.	All geoengineering proposals

Instrument (Membership)	Treaty's main objective	Articles, protocols or amendments of potential relevance to geoengineering	Technologies of potential relevance
United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa (UNCCD) <i>(196 parties)</i>	Aims to combat desertification and mitigate the effects of drought.	The Convention encourages national programs and international cooperation targeting desertification. It is relevant to geoengineering to the extent that these may affect the hydrological cycle.	All geoengineering proposals
Outer space treaties (OSTs) <i>(104 parties - includes US, Russia, EU, Australia and China)</i>	Establishes the legal framework for international space law.	Requires that space exploration “ <i>be carried out for the benefit and in the interests of all countries [...] and shall be the province of all mankind</i> ” (<i>Outer Space Treaty</i> art I) Any use of space must be for peaceful purposes (<i>Outer Space Treaty</i> art IV) and a launching State is liable for damage caused by its space object (<i>Space Liability Convention</i> art II)	Space-based SRM
Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD) <i>(77 parties - includes, the EU, the US, Russia and China)</i>	Prohibits military or hostile usage of environmental modification.	Environmental modification is defined as “ <i>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</i> ” (<i>ENMOD Convention</i> art II). The Convention promotes research into, and collaboration on such activities if they are for peaceful purposes (Winter 2011). Prohibition applies only if another contracting Party endures destruction, damage or injury that is widespread, long-lasting or severe (Lin 2009).	All geoengineering proposals
Antarctic Treaty System (ATS) <i>(53 parties, only 29 with voting status - includes the US, Russia, Australia and some EU countries)</i>	Regulates the use of Antarctica.	The Convention's Protocol on Environmental Protection to the Antarctic Treaty requires that activities be planned and conducted to avoid “ <i>adverse effects on climate or weather patterns</i> ” (<i>PEPAT</i> art 3.2(b)(i)). Scientific research into geoengineering, such as ocean fertilisation, would be permitted with a requirement for “ <i>due consideration [...] to avoid detrimental effects on dependent and associated ecosystems, outside the Antarctic Treaty area</i> ” (Lin 2009), “ <i>significant adverse effects on air or water quality</i> ”; or “ <i>significant changes in the atmospheric, terrestrial (including aquatic), glacial or marine environments</i> ” (Scott 2012)	All geoengineering proposals

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Fig. 1

