

Geoengineering in a climate emergency

Exploring governance pathways and pitfalls

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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ABSTRACT

Geoengineering has been advanced as a possible emergency option to sudden and disruptive climate change—a climate emergency. This paper advances the nascent geoengineering governance discourse, looking specifically on issues and challenges relating to how geoengineering can be used as a remedial option in case of a climate emergency. The main contribution of this paper is the examination of six potential governance alternatives for geoengineering, assessed according to three fundamental characteristics that the paper argues any geoengineering regime must evince, to wit, holism, adaptability and legitimacy. Using path-dependency theory, it further explores how the current parochialism and fragmentation in global governance could affect the long-term development of the geoengineering discourse, before finally looking at how unilateral geoengineering could result from a global discourse on catastrophic climate change gone astray. High levels of complexity, risk and uncertainty are inherent in both climate change and geoengineering and present substantial obstacles in the development of geoengineering governance. The fundamental question of this paper is how we can foster robust and resilient governance and responses for climate change and other environmental problems.

TABLE OF CONTENTS

Author's Declaration.....	ii
Abstract.....	iii
List of Tables	v
1. Introduction.....	1
2. Literature review.....	5
3. Governance pathways.....	24
3.1. Expanding the discourse.....	24
3.2. Three virtues to ask of any geoengineering regime	28
3.2.1. It should be holistic.....	29
3.2.2. It should be adaptive.....	31
3.2.3. It should be legitimate	33
3.3. Governance pathways and frameworks for geoengineering	36
3.3.1. Composite governance	36
3.3.2. Scientific governance	38
3.3.3. International financial institutions.....	41
3.3.4. The G20.....	44
3.3.5. The United Nations Security Council.....	46
3.3.6. Novel forms of governance	50
4. Geoengineering under a climate emergency.....	51
4.1. Looming threats: what is a climate emergency?	51
4.2. Responding to abrupt climate change	55
4.3. Different governance paths, different outcomes	57
5. Unilateral geoengineering.....	61
5.1. Unilateralism and the case of a missing global consensus.....	61
5.2. The strategic dilemma of unilateral action	63
6. Conclusion	68
Bibliography	71

LIST OF TABLES

Table 1: Prisoner's Dilemma	64
Table 2: Chicken	64
Table 3: Deadlock.....	64
Table 4: Bully	64

1. INTRODUCTION

Over thousands of years of burning wood and other biofuels, clearing forests, and agricultural development, humans have released substantial amounts of greenhouse gases (GHGs) into the atmosphere, affecting the global climate in such a profound way that we may have facilitated the meteoric rise of our own species (Richter & Mobley, 2009; Ruddiman, 2003; Zalasiewicz et al., 2008). Unwittingly, we created a congenial and relatively stable climate for ourselves. Yet mounting evidence tells us that the Earth's atmospheric temperature is not only leaving behind those familiar levels that allowed human life to flourish, but may as a consequence be about to be profoundly disturbed, jolted out of its relatively stable state and into a new and considerably warmer one (Hansen, 2006; Hansen et al., 2007; Kriegler, Hall, Held, Dawson, & Schellnhuber, 2009; Lenton, Held, & Kreigler, 2008). The dramatic decline in Arctic summer sea ice in 2007 suggests that we may be close to a climate threshold or "tipping point" in the Arctic that could trigger rapid global climate change (Comiso, Parkinson, Gersten, & Stock, 2008; Lenton et al., 2008; Maslanik et al., 2007; Perovich et al., 2007; Sommerkorn et al., 2009). The danger is not merely that we may encounter a tipping point, but that if we do, we may incur irreversible damage. We may not be able to go back across a threshold once it is crossed.

We cannot take for granted that we *will* cross a tipping point, especially since we may yet have the power to prevent it. Still, the risk of irreversible damage to the planet in the context of failing mitigation policies dictate that we ought to prepare for the possibility (K. Anderson & Bows, 2008; Helm, 2008; M. Meinshausen et al., 2009; Prins & Rayner, 2007). To that end, a growing number of scientists are contemplating the possibility of engineering the climate (geoengineering) to moderate the impact of climate change, perhaps also to reduce the level of

carbon dioxide (CO₂) in the atmosphere (e.g. Crutzen, 2006; Govindasamy, Caldeira, & Duffy, 2003; Keith, Ha-Duong, & Stolaroff, 2006; Keith, 2000a; MacCracken, 2009). Long banished from mainstream science, the concept of geoengineering is gradually becoming more accepted, and the science behind it is starting to mature (Cicerone, 2006).

Scientists are thus giving policy-makers tools other than mitigation to reign in global warming. The onus is now increasingly on the international community to decide how and under what conditions it should make use of this knowledge, including the question of whether we should develop geoengineering capabilities, and how potentially invasive research may be conducted. Geoengineering is politically difficult, implicating questions of justice, equity and acceptable risk (Jamieson, 1996; Lin, 2009; Victor, 2008), and it exposes more fundamental questions about how far we should go in trying to control nature (Keith, 2000b; Kiehl, 2006; Weitzman, 2009). Allegations of hubris have been legion: engineering the climate increases rather than decreases human influence on the planet, contradicting the goals of the GHG mitigation process. Various geoengineering techniques have furthermore been associated with a range of severe side-effects, from ozone depletion to monsoon weakening, which has triggered deep scepticism towards the entire field (Kiehl, 2006; Lawrence, 2006; Lovelock, 2008; Schneider, 2008).

The risks of geoengineering are not trivial, but the social and ecological consequences from abrupt or unchecked climate change may be worse still. One of the fundamental—but perhaps unanswerable—questions we must pose is what level of risk is acceptable. Related questions include what values—and whose—should guide our decisions. How can the world's nations and peoples come together to decide—justly, fairly and amicably—whether geoengineering should

be used? Geoengineering has properties that have raised concerns that countries may choose to go ahead with it unilaterally (Keith, 2000a; Victor, 2008), further complicating the picture.

An international political process must be set in motion in to prepare for the management and governance of the issue in case geoengineering is at some point considered necessary. This paper aims to engage with and expand the literature on geoengineering governance, mainly by asking how the issue could or ought to be governed and managed on the global level, especially in case of a “climate emergency,” or abrupt climate change.¹ At this point in time, geoengineering governance can go down several different paths. Using path-dependency theory, this paper argues that we must be careful how we proceed with the geoengineering discourse, lest we get locked into wrong trajectory (Bennett & Elman, 2006; Pierson, 2000, 1993). If we do, it might be difficult to reverse course later. More than that, however, we must ensure that we have a diverse set of options both in terms of how we can react to—or possibly pre-empt—a climate emergency, as well as for how we govern the issue.

The paper picks up and expands upon the discourse from the point where it is left by previous contributions, notably by Lin (2009) and Virgoe (2009), who at the time of writing offer the latest and most comprehensive peer-reviewed assessments of international governance models for geoengineering. Section 2 reviews the state of geoengineering literature, with a focus on identifying gaps in the literature, as well as areas other authors have suggested needs attention. In addition, it briefly introduces new areas where this paper expands the discourse in later sections.

¹ The phrase “climate emergency” may be unclear or even controversial. In this paper it is taken to mean a situation of abrupt and disruptive climate change (Blackstock et al., 2009), but as discussed in Section 4, it may have different connotations for different people (Dessai et al., 2004).

Section 3 builds on the foundation laid by Lin (2009), Virgoe (2009) and other authors: what organizations, forums or international spaces could handle the various governance challenges, striking a balance between all the difficult political considerations and the demands of exigency? It also reviews characteristics that an ideal geoengineering regime ought to exhibit—yardsticks for geoengineering governance. Section 4 examines the politics of climate emergencies, including how path-dependency may influence the unfolding of events and even precipitate unilateral action. Section 5 then looks at geoengineering and unilateralism through the lens of game theory, trying to discern some of the strategic decisions countries may have to make in a climate emergency.

Complexity is the overarching theme of this paper. From the global climate to the international political arena, complex systems are implicated throughout the entire paper.² In the Earth system, self-reinforcing (positive) feedback loops represent a major factor behind the potential for non-linear behaviour and discontinuities (Alley et al., 2003; Lenton et al., 2008; Scheffer et al., 2009). Complexity, however, shrouds forecasts behind an opaque veil of uncertainty, with regards to both risks and consequences. In the social realm, managing this uncertainty and making appropriate, rational decisions based on incomplete information about probability and risk become substantial obstacles (Weitzman, 2009). Social systems too behave in complex ways. The later discussion of path-dependency in socio-political systems implicates reflexivity, discontinuity and sensitivity to small changes in essential variables (Bennett & Elman, 2006; Pierson, 2000, 1993).

² Complex systems refer to both socio-political and biogeophysical systems that evince properties and behaviour such as emergence, non-linearity, feedback loops and self-organization (Sterman, 2006).

Irreducible uncertainty spells fundamental consequences for how issues can be effectively resolved in socio-political systems (Folke, Hahn, Olsson, & Norberg, 2005; Weitzman, 2009). Fortunately, a growing field of research is exploring how governance systems can manage complex biogeophysical systems. Complexity may not only require its own set of conceptual and investigative tools, but also its own governance architecture (e.g. Folke et al., 2002; Folke et al., 2005; Gunderson, 1999; Olsson et al., 2006). This paper engages with part of the growing literature on resilience and adaptive management, exploring how it can be applied to the discourse on geoengineering governance.

2. LITERATURE REVIEW

Scant attention has been given yet to geoengineering governance—the discourse around geoengineering is still largely confined to scientific and technical issues, with few efforts to tackle political, economical and social issues (e.g. Barrett, 2008; Bodansky, 1996; Jamieson, 1996; Lawrence, 2006; Lin, 2009; Virgoe, 2009). Researchers who have explored these issues express concern for how geoengineering might be managed, issues of ethics and equity, and problems that could arise from unilateral geoengineering. Very little attention has been given to practical considerations, which is where this paper makes its main contribution. This section reviews the extant geoengineering literature, with a particular focus on socio-political and regulatory issues. First, it offers an overview of what has been written about geoengineering and geoengineering governance in particular; second, it identifies some of the gaps in the extant literature as well as areas where it suggests future effort is needed; and third, it introduces how this paper intends to expand the discourse.

Also known as “climate engineering” (Bodansky, 1996) or “Earth systems engineering,” (Schneider, 2001) geoengineering has been defined as projects that “involve large-scale engineering of our environment in order to combat or counteract the effects of changes in atmospheric chemistry.” (National Academy of Sciences, 1992, p. 433) In the literature, geoengineering has been presented in several ways; one, as a substitute for mitigation (Bodansky, 1996; Victor, 2008); two, in combination with mitigation, to give us a longer window of opportunity to cut emissions (Wigley, 2006); three, as a response to overshooting either a set CO₂ loading or temperature level (Boucher, Lowe, & C. D. Jones, 2009); and four, as a response to abrupt climate change (Blackstock et al., 2009).

The chief reason is that mitigation efforts are falling far short of what is required, increasing the risk that we will come to experience the “fat tail” of climate change (Crutzen, 2006; Schneider, 2008; Virgoe, 2009; Weitzman, 2009)—that is, the severe but low-probability upper end of global warming predictions (Weitzman, 2009). The fat tail of climate change does not necessarily entail tipping points (Intergovernmental Panel on Climate Change [IPCC], 2007a; Scholze, Knorr, Arnell, & Prentice, 2006; Solomon, Plattner, Knutti, & Friedlingstein, 2009). Yet hard limits on what is objectively knowable confound attempts to quantify and predict future behaviour of the climate system (Weitzman, 2009). In the absence of concrete knowledge about probability, abrupt climate change is placed in the fat tail of normal distributions of risk—in other words, deemed exceedingly rare—and is often excluded from risk analysis.

This paper addresses geoengineering as a response option to abrupt climate change. In technical terms, abrupt climate change could occur when the climate system is forced across a threshold, spurring dramatic changes as the system moves to a new and warmer baseline (Alley et al., 2003;

Hansen, 2006; Hansen et al., 2007; Lenton et al., 2008). Numerous geoengineering techniques have been proposed to deal with this; one such example is a proposal to fertilize the oceans with iron—a limiting nutrient—with the goal of increasing their capacity as carbon sinks through the proliferation and death of algae, which, it is posited, would effectively removing their store of carbon from the carbon cycle (Lampitt et al., 2008; Smetacek & Naqvi, 2008). It would be a slow process, and as such is better suited to long-term corrections of the climate than as an emergency remedial intervention.

Far quicker is the proposal to cool the Earth by infusing the stratosphere with sulphur dioxide (SO₂) particles to increase the Earth's reflectivity (albedo) (Crutzen, 2006; Govindasamy et al., 2003; Lenton & Vaughan, 2009; Rasch et al., 2008). Ship-based cloud generation is another proposal in the same category (Salter, Sortino, & Latham, 2008). A more fringe proposal is to attempt to filter out sunlight with trillions of little sunshades placed in space between the Earth and the Sun (Angel, 2006). Because of the logistical, technical and financial barriers to implementing this project—with a cost estimate of approximately US\$5 trillion³—it is probably one of the least realistic geoengineering proposals.

The crucial difference between the schemes is how they propose to affect the climate: either by reducing the loading of GHGs in the atmosphere, which in turn would affect global temperatures, or by blocking or reflecting sunlight to affect the temperature directly (The Royal Society, 2009). The first example described above—ocean fertilization—is part of a slate of projects that would remove CO₂ from the carbon cycle. In the long term, this could eventually realign the

³ A note on money: all sums are quoted directly, not converted to current amounts.

atmospheric CO₂ loading and the tropospheric average temperature with their pre-industrial levels. It includes other options as well, such as reforestation (The Royal Society, 2009) or the construction of machines that can remove CO₂ directly from the air (Keith et al., 2006; Lackner & Brennan, 2009).

Stratospheric sunshields fall into the category of schemes known as “solar radiation management” (SRM) (The Royal Society, 2009), “albedo enhancement” (Crutzen, 2006), or “shortwave climate engineering” (Blackstock et al., 2009). These are projects whose goal is to counteract the increasing positive forcing from GHGs in the atmosphere, but do nothing to remediate the atmospheric GHG loading, thereby addressing the symptom—warming—rather than the cause (Kiehl, 2006). Some SRM schemes aim to induce cloud formation (Latham et al., 2008; Salter et al., 2008); others to increase the albedo of land surfaces, for example through brightening or “whitening” human infrastructure, or engineering more reflective crops (Hamwey, 2007; Ridgwell, Singarayer, Hetherington, & Valdes, 2009). Of the proposed SRM schemes, however, it is stratospheric geoengineering that has been given the most attention by scientists, owing largely to its promise of rapid deployment and rapid cooling (The Royal Society, 2009), and because injecting sulphates into the atmosphere should produce effects similar to that of naturally occurring volcanic eruptions (Crutzen, 2006; Robock, 2000).

Although there has been a nascent interest in the concept since 2006, when the journal *Climatic Science* ran a special edition around an article by Paul Crutzen (2006), geoengineering has been a taboo subject among climate scientists for most of the time since its inception—and it is still highly controversial (Cicerone, 2006; Schneider, 2008; Lawrence, 2006). Critics complain about the hubris of thinking we can successfully set the Earth’s thermostat (Kiehl, 2006; Virgoe, 2009;

Weitzman, 2009). Our knowledge of how the climate behaves is limited and fraught with uncertainty, and geoengineering might cause large-scale disturbances in weather and precipitation patterns (Hegerl & Solomon, 2009; Leovy, 2009; Robock, 2008). Crucially, it is unlikely that these disturbances will be distributed equitably: some will win and some will lose, which contributes to the controversy of geoengineering (Jamieson, 1996). SRM lays itself open to even more criticism, as it mitigates the effects of radiative forcing but does nothing about their root causes (Kiehl, 2006), while possibly exacerbating other problems such as ozone depletion (Tilmes, Mueller, & Salawitch, 2008). At the same time, GHGs would be allowed to continue to accumulate in the atmosphere, letting the acidification of the oceans continue unabated, with adverse effects for marine life (Raven et al., 2005). Robock (2008) is less than optimistic about the prospect of avoiding serious side-effects if geoengineering is deployed, writing about the potential for both known and unknown side-effects. The risk of severe and possibly irreversible environmental damage poses significant ethical challenges for putative geoengineers and researchers (Hegerl & Solomon, 2009; Leovy, 2009; Robock, 2008).

Many are also concerned about the moral hazard introduced by all geoengineering schemes—that the world could, consciously or not, fail to pursue mitigation options as vigorously as it otherwise would, knowing that there is a fall-back option (Keith, 2000a; Victor, 2008; Virgoe, 2009). Adding to this concern are calculations that geoengineering could turn out to be orders of magnitude cheaper than mitigation based on emission reductions, further increasing its attractiveness (Barrett, 2008). If we exclude Angel's (2006) spaced-based scheme, cost estimates range from a few billion dollars to a few tens of billions a year (Barrett, 2008; Keith, 2000a; Keith & Dowlatabadi, 1992), though they include only the direct costs of geoengineering, leaving out the costs of side-effects. Because of this accounting trick, and because we might

require a whole range of different interventions using different techniques, Victor (2008) says we should not count on geoengineering being the least expensive option.

The ostensibly low cost of geoengineering nevertheless introduces a significant problem, often mentioned in geoengineering literature: the possibility that faced with an existential threat, a lone country or a small group of countries could start geoengineering unilaterally (Keith, 2000a; Lawrence, 2006; Lin, 2009; Victor, 2008; Virgoe, 2009). A central fear is that other countries may take exception, perceiving threats to their national security and sovereignty from adverse effects induced by geoengineering. An opinion piece in the magazine *Foreign Policy* also voiced the concern that geoengineering itself could be turned into an offensive weapon (Cascio, 2008). So far, this possibility has not been explored more thoroughly, but whether geoengineering can threaten international security or not, the consensus is that the low cost and low barriers of geoengineering does pose significant governance challenges (Keith, 2000a; Lawrence, 2006; Lin, 2009; Victor, 2008; Virgoe, 2009).

A further cause for concern is that a scheme like a stratospheric sunshield requires a significant political commitment, not just in order to begin the project, but also to keep it going, perhaps for as long as several decades or even centuries (Bengtsson, 2006; Boucher et al., 2009). Once begun, the price of quitting might be steep: the temperature could spike sharply as the effect of the sunshield is unmasked. Were this to happen, we would also feel the effect of the CO₂ emissions that would have taken place since the experiment was started (Matthews & Caldeira, 2007). MacCracken (2006) expresses doubt that a global geoengineering could be sustained for that long, although Victor (2008) comments that the threat of terrible consequences if the project were stopped could force opponents to support it.

Albeit leery of the proposal, a growing number of researchers nevertheless find geoengineering hard to reject or ignore, expressing serious concern over the will and ability of the world to cut emissions fast enough (e.g. Crutzen, 2006; MacCracken, 2009; Victor, 2008; Virgoe, 2009). Yet, because climate researchers have only recently started to take geoengineering seriously, there is little treatment of geoengineering yet in reports from the IPCC (2007b). Its fourth assessment report regarded geoengineering options as “largely speculative and unproven and with the risk of unknown side-effects.” (IPCC, 2007b, p. 15) Assessment has nevertheless begun, with organizations such as the Royal Society (2009) publishing a report—the most comprehensive yet—on the feasibility various geoengineering schemes, both in technical and political terms. Following the increasing interest in geoengineering, the IPCC declared that geoengineering will be given extensive treatment in the next assessment report, due in 2014 (Pachauri, 2009).

The rise in political salience of geoengineering and the possibility that it may provide essential tools in responding to climate change means that how it could be managed and governed on the global level—because it is a global concern—must now be resolved (e.g. Lin, 2009; Victor, 2008; Virgoe, 2009). Should geoengineering be used? If so, under what circumstances? Who should be allowed to use it, and who could legitimately authorize a climate intervention? Although the issue is growing in prominence, only a handful of academic papers considering geoengineering governance were available at the time of writing. The recent geoengineering report by the Royal Society (2009) included a brief chapter on governance, but no substantive reports on geoengineering governance yet exist. As alluded to above, what extant literature there is concerns itself largely with issues of ethics and the theoretical foundations of the politics of geoengineering, and environmental and political constraints inherent in the nature of most geoengineering schemes. The literature also notes many open questions and challenges that must

be resolved, such as who should be allowed to make decisions that affect the whole world, how to “ensure [that] decisions are made on a sound scientific basis,” (Bodansky, 1996, p. 310) and whether winners should compensate losers (Jamieson, 1996), as well as other questions of ethics, fairness and equity.

These concerns, says Virgoe (2009), are among the key questions a geoengineering regime must resolve, in addition to controlling the political and legal mandate of climate interventions. Schelling (1996) imagines that the regime would have to make decisions about what kind of geoengineering should be deployed and to what extent, but that mainly, its task would be managing cost-sharing schemes. The operational side, however, should be outsourced by the regime to a designated agency or party.

Carlin (2006b, pp. 9-12) presents a list of eight (seven if we exclude the last category, which is essentially “miscellaneous”) qualifications that he believes a climate governance model must fulfill, though these apply to a regime with a much broader mandate (mitigation *and* geoengineering). Carlin’s criteria relate mostly to economical and political viability, including cost effectiveness, distributional equity, policy flexibility, and the claim that a regime can afford neither “undue demands on participation and compliance” nor “other major environmental risks.” Of the seven characteristics, only one mentions the regime’s *raison d’être*—the sole reason it is needed in the first place—which is vaguely referred to as an “effective environmental outcome,” without much elaboration. Section 3 offers a critique of Carlin’s focus, arguing that we must define the environmental goals of a regime first: if enough of these are sacrificed in order to achieve political agreement, the regime may be reduced to a political circus at best and a hindrance at worst.

Above all, the literature works to distinguish geoengineering from climate change mitigation and to stress that emission reductions must remain the main avenue of mitigation (e.g. Crutzen, 2006; Keith, 2000a; Kiehl, 2006; Wigley, 2006). Geoengineering, notes Victor (2008, p. 323), “turns the politics of climate protection upside-down,” because global coordination of emission reductions has proven so difficult. By contrast, it is alleged that geoengineering turns the extremely difficult effort of coordination into one of cost-sharing, which might greatly simplify collective action (Schelling, 1996).

Collective action has been the Achilles’ Heel of climate change mitigation, because of the inadequacies of international treaties, the standard tool of norm-creation for global environmental problems (e.g. Lin, 2009; Ralston, 2009; Thompson, 2006; Victor, 2008; Virgoe, 2009). Many have pointed out the difficulties of consensus-based treaty processes in the context of climate change: they are riddled with differential incentives and motivations, disparities in the distribution of costs and benefits, the problem of free-riding, and the effective veto of every participating government when agreement hinges on universal consent (e.g. Barrett, 2008; Lin, 2009; Michaelson, 1998; Ralston, 2009; Victor, 2008; Virgoe, 2009). Michaelson (1998) adds that geoengineering avoids the “tragedy of the commons” by not imposing costs on, or requiring behaviour modification from, powerful economic actors such as power utilities and heavy industry.

Ralston (2009) explains the strategic implications of collective action on climate change through game theory, building on the work of Hardin (2008). Game theory describes a way of modelling situations of strategic interaction, in which two or more parties must decide on a course of action

that will affect the other (Snyder & Diesing, 1977). According to Snyder and Diesing (1977, p. 37), game theory models focus on

strategies available to the players, each of whom is trying to maximize his own gain (or minimize his loss) in the knowledge that the other is trying to do the same. The parties are interdependent in the sense that the outcome depends on the opponent's choice of strategy as well as on one's own.

The “Prisoner’s Dilemma” is a famous game theory model often used in international relations, describing a situation where two prisoners, unable to communicate, are encouraged to incriminate each other (Snyder & Diesing, 1977). Their fates are intertwined: if neither decides to cooperate, they know the prosecutor does not have enough evidence to lock them up for more than a year. If, however, one agrees to cooperate while the other does not, the latter would receive 10 years while the former would be granted immunity. If they both denounce each other, they both get five years. In this situation, the rational course of action is to maximize your potential reward—immunity—while minimizing your potential risk—10 years in prison. Collectively, on the other hand, they would both be better off by refusing to cooperate—if only they could trust each other.

Ralston (2009) uses game theory to bolster the claim that geoengineering can simplify collective action. When it comes to normal mitigation strategies, the “tragedy of the commons” that has befallen globally shared resources such as the atmosphere has created a Prisoner’s Dilemma, a situation where maximum individual pay-offs do not come from cooperation, but from free-riding. This explains why countries have so little interest in reducing their emissions—even why, in a narrow sense, it is the rational thing to do. Ralston concludes, along Schelling’s (1996) lines, that the coordination problems around climate change action may thus give geoengineering an

inordinate advantage over both mitigation and adaptation, when these two are bogged down in the politics of free-riding and the tragedy of the commons.

Regardless of its potential governance advantages relative to collective emission reductions, however, geoengineering is not popular (Robock, 2008; Victor, Morgan, Apt, Steinbruner, & Ricke, 2009). Because of the many liabilities and moral hazard associated with geoengineering, Bodansky (1996) and Victor (2008) write that world opinion has been turning towards a complete ban on any sort of geoengineering. Victor warns that despite the problems associated with a lack of global regulations, attempts to codify rules today would likely be counterproductive. Part of the problem is that most countries would probably favour a total ban precisely because of the side-effects and moral hazard, whereas would-be geoengineers would likely balk, and would not be bound by the ban. Another part is a significant danger of institutionalizing anti-geoengineering sentiments. International regulatory bodies are already turning towards the prohibition of geoengineering (Rayfuse, Lawrence, & Gjerde, 2008; Virgoe, 2009).

For some, that is a favourable development. Lin (2009) favours Cicerone's (2006) recommendation of a ban—a “default presumption” against geoengineering (Lin, 2009, p. 23)—as the baseline from which we can then proceed. Lin (2009, p. 19) is nevertheless concerned about underinvestment in geoengineering research, stating that experimentation will be necessary: “failing to address geoengineering research needs as well as potential geoengineering deployment heightens the risk that events will unfold in ways that are less than desirable.” In the next section, this paper argues that these two may be connected: that a baseline ban may hamper

research efforts and necessary experimentation, and lead to the institutionalization of anti-geoengineering sentiments against which Victor (2008) cautions us.

To avoid formal bans on geoengineering, Victor (2008) argues that norms must be allowed to transpire organically “bottom-up” rather than be imposed “top-down”. Geoengineering research is nevertheless an area in need of regulation; experiments cannot proceed without oversight. A proposal has emerged that science must self-regulate; scientists should commit themselves to strong and open ethical norms (Morrow, Kopp, & Oppenheimer, 2009). But do scientific communities have the right to use the atmosphere or the oceans as a testing ground for unproven technology with a plethora of unsavoury side-effects? And who should conduct these experiments? The consensus-based IPCC process, writes Victor (2008), is ill-equipped to handle geoengineering research, owing to the high uncertainty of the underlying science, the inability of science to conclusively resolve controversies, and the focus on reviewing only published literature. Instead, he says research should be decentralised, carried out by multiple, strong, competent research bodies, such as national science academies. Together, they would produce a plurality of ideas and opinions rather than consensus.

But all these considerations leave out the important issue of what country or organization should or could bear the responsibility—or privilege—of governing geoengineering on a global basis. Current governance with a bearing on geoengineering is sparse; in fact, no existing international treaties deals explicitly with geoengineering (Virgoe, 2009). Nevertheless, international law is not completely silent on the issue. First of all, Bodansky (1996) and the Royal Society (2009) both point out that a fundamental principle of international environmental law is that states must try to prevent transboundary harm. In addition, there is the weaker precautionary principle.

Second, several authors (e.g. Bodansky, 1996; Lin, 2009; Virgoe, 2009) further remind us that there *is* a relevant treaty for climate change governance in general: the United Nations (UN) Framework Convention for Climate Change (UNFCCC). It is noted, on the other hand, that it is heavily predicated on emission reductions as the main mitigation mechanism, and lacks any mention of geoengineering or avenues for dealing with active climate manipulation. It would even seem that geoengineering by definition contradicts its mandate, which is to “prevent dangerous anthropogenic interference with the climate system.” (Lin, 2009, p. 15)

Despite the short-comings of multilateral consensus-building, the prevailing view seems to be that geoengineering governance must be dealt with on a multilateral basis, and that the UNFCCC is the most obvious multilateral governance body (Barrett, 2008; Bodansky, 1996; Lin, 2009; Virgoe, 2009). Indeed, Lin (2009) and Barrett (2008) argue that the UNFCCC is the ideal venue for geoengineering regulation, because, as an existing agreement with near universal membership, it already has the necessary support structures and an established forum for negotiation in the Conferences of the Parties. Because geoengineering can potentially be substituted for emission reductions, Lin (2009) further writes that geoengineering *does* appear to fall within the purview of the UNFCCC, though he acknowledges the difficulties involved in formalising this. In his view, it makes little sense to create a separate institution to deal with geoengineering.

Beyond the UNFCCC, a few other existing governance mechanisms are also discussed in the literature. Virgoe (2009) points out relatively recent developments in geoengineering research by the Convention on the Protection of Biological Diversity (CBD), which called for a moratorium on ocean fertilization in June of 2008. In a similar vein, Rayfuse et al. (2008) write that the

governing body of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (London Convention) adopted a statement of concern about ocean fertilization, and declared such activities to fall within its domain. These are so far the only the international governing bodies to have made explicit mention of geoengineering in their work, but other international agreement may apply without requiring amendments.

Several authors discuss to what extent the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD) applies to geoengineering (Bodansky, 1996; MacCracken, 2006; Virgoe, 2009). ENMOD is a ban on modifying the weather for hostile purposes—in other words modifying the weather in order to harm other countries. MacCracken (2006) argues that ENMOD effectively makes geoengineering illegal. Virgoe (2009) counters that ENMOD only forbids weather modification for hostile purposes, while explicitly allowing peaceful weather modification, though his criticism appears to read MacCracken (2006) incorrectly. MacCracken's observation is rather that the perception of geoengineering is subjective and socially constructed: some countries *may* perceive geoengineering to be a threat to their climatic stability and environment. MacCracken considers the chances that someone *will* perceive it as an act of hostility as fairly high. Lin (2009), however, remarks that ENMOD is nevertheless a rather obscure treaty with few signatories, which means its impact would likely be limited.

The UN Environment Programme's Guidelines on Weather modification are also too limited to apply to geoengineering (Bodansky, 1996), but the UN Convention on the Law of the Sea (UNCLOS) and the Antarctic Treaty are seen as more consequential (Bodansky, 1996; The Royal Society, 2009). Like all other treaties, they lack any direct provisions for geoengineering,

but UNCLOS prohibits oceanic pollution within its ambit. It is permissive of scientific research, however, and does not designate authority to any institutions to regulate geoengineering on the high seas, outside of countries' exclusive economic zones.

Similarly, atmospheric governance regimes could also potentially regulate geoengineering activities. First of all, the airspace directly above each country's territory and ascending into space is part of that country's sovereign claim (Bodansky, 1996). But international regulatory frameworks also apply, such as the Long-Range Transboundary Air Pollution Convention (LRTAP), which contains protocols that regulate specific forms of pollution, like SO₂ (Bodansky, 1996; Virgoe, 2009). The Antarctic Treaty, too, would have authority over certain climate interventions within its jurisdiction, based on its conservation and pollution control mandate (Bodansky, 1996). Towards the end of his paper, Virgoe (2009) further considers the possibility that geoengineering could be deployed by a consortium of countries acting on their own, perhaps modelled after the Carbon Sequestration Leadership Forum. He ends his thoughts at this point, however, leaving an obvious area to explore further, which this paper does in the next section.

Sensitive to the problems associated with consensus-oriented collective action, Lin (2009) discusses the viability of non-consensus arrangements, under which decisions can be made by some form of majority rather than unanimity. Although such arrangements must surmount tough obstacles like sovereignty and legitimacy, he points out that several treaties have non-consensus rule-making mechanisms, albeit only for small and incremental changes. A way to overcome this is to take an adaptive management approach, "to develop a protocol that treats geoengineering governance as a series of adaptive management decisions, rather than as a single binary choice to

be made once and for all.” (Lin, 2009, p. 22) Incremental non-consensus decisions are easier to accept than dramatic ones, and through regular updates and consultations the situation can be reassessed, reducing the stakes involved at each junction and keeping the dialogue open.

Whereas Lin (2009) emphasises the political dimensions and benefits of adaptive management, Virgoe (2009) highlights environmental factors. Because of the massive uncertainty inherent in any type of geoengineering, it is very probable that adjustments will be needed as the project unfurls, as its effectiveness becomes understood and as side-effects become known—a process of experimentation with which traditional governance models are not apt to cope. Adaptive management arose in the 1970s as a new way for environmental managers to handle uncertainty (Cooney & Lang, 2007; Folke et al., 2002; Gunderson, 1999; Holling, 1978), without “assuming away” the uncertainty or creating “spurious certitude” by breaking “the problem or issue into trivial questions spawning answers and policy actions that are unambiguously ‘correct,’ but, in the end, are either irrelevant or pathologic.” (Gunderson, 1999, p. 1) Consequently, “adaptive management therefore views policy as hypotheses,” writes Gunderson (1999, p. 2), “that is, most policies are really questions masquerading as answers.” A core tenet of adaptive management, mentioned by Virgoe (2009), is the emphasis on flexibility and continual modification—experimentation—to deal with surprises and unexpected events, which can never be reduced to a level where they can be understood (Folke et al., 2002; Folke et al., 2005). Fostering resilience is another core tenet, defined as the capacity of a system to absorb shocks without changing in fundamental ways (Folke et al., 2002; Gunderson, 1999). A key feature of resilient systems is that they have multiple pathways for providing the same services or achieving the same result. Section 3 explores this issue further in the context of geoengineering and abrupt climate change.

Virgoe (2009) notes, however, citing Thompson (2006), that adaptive management is not a “silver bullet” approach: its management structure tends to be top-down and centralized, which is not politically feasible on the international stage. Other perspectives on the problem may therefore be necessary as well. This paper argues in Section 3 that a perspective on how to organize scientific-societal relations called “post-normal science” applies well to geoengineering (Funtowicz & Ravetz, 1993, 1999; Ravetz, 1999). One of the great problems in environmental governance is dealing with uncertainty and risk, when there is a “plurality of legitimate perspectives” (Etkin & Ho, 2007, p. 627). Science is intrinsically linked to—but cannot adjudicate—difficult questions of social values and trade-offs implicated by geoengineering. “The maintenance and enhancement of quality, rather than the establishment of truth,” writes Ravetz (1999, p. 653), “is the key problem for science in the post-normal age.” With high risk, high uncertainty, divided opinions, and the inability of science to offer conclusive answers to all the questions of policy-makers, the twin issue of climate change and geoengineering are very much post-normal.

If existing governance models—of which only the treaty model is considered at any length in the literature—are inadequate, with what should we replace them? The treatment of alternatives is altogether too brief, which suggests an obvious area for expansion of the literature. This is explored in the next section. This paper argues that the recent events in geoengineering governance involving the CBD and the London Convention also require more scrutiny. They have not received much attention in the literature, but may have profound consequences. Section 3 of this paper uses path-dependency theory to analyze how the politics of geoengineering might unfold, and considers how the recent movements toward a ban on geoengineering may become entrenched in the status quo. Specifically, it builds on Victor’s (2008) warning against a taboo on

geoengineering, arguing that a taboo may come to exert a negative influence over the future development of geoengineering governance through path-dependency.

Path-dependency theory is a tool for studying of how choices we make or events that occur in the present period can influence our options in the next period (Bennett & Elman, 2006; Pierson, 2000, 1993). In a broad sense, path-dependency can be taken to mean merely that “history matters.” In a narrower sense, however, there are situations when one critical decision or event has an impact on all our later options, understood as “critical junctures.” The implication is that whatever choice is made at a critical juncture, once we start down a particular path, dictated by that juncture, we become “locked in.” The cost of breaking out will be high, if at all possible. As discussed in Section 4, this may have significant consequences for the development of the geoengineering discourse.

Another area that requires further analysis is the portents of unilateral geoengineering, and the potential consequences thereof. Many point out the dangers of unilateralism, yet insufficient efforts have so far been made to try to understand how and why countries may choose to “go it alone,” as it were, as well as the fall-out of such events. Victor (2008) calls for the study of the likelihood and consequences of unilateral geoengineering through war games. A full-blown war game is obviously a bit involved for this paper, but it does argue that game theory can be a useful complement and begin the work that Victor says has to be done. Game theory was used by Ralston (2009) to explain how cooperation problems around mitigation and adaptation might lead to geoengineering, but has not yet been extended to geoengineering proper. In Section 5, this paper uses game theory to analyze the strategic choices countries might encounter under a situation of abrupt climate change. This section discusses additional game theoretic models,

which it argues more closely captures the strategic situation of global climate change governance, where each player is not necessarily confronted with the same promises of pay-off or loss. These game types are asymmetric, as opposed to the Prisoner's Dilemma, where both players are presented with the same risks and rewards (Snyder & Diesing, 1977).

The discussion about geoengineering is still very much in its infancy, and has revolved around a few extant political tools and institutions. A lot of attention has been given to the current mode of climate governance—consensus-based treaty-making under the UNFCCC umbrella—though it is clear that significant obstacles are in the way. No other comprehensive governance model, however, has presented itself as credible to geoengineering governance reviewers. Thus, between the choice of a UNFCCC regime or no governance at all, the preference seems to be the UNFCCC.

Yet many other potential actors, networks and arenas remain unexamined. The adaptive governance discussion shows the willingness of geoengineering researchers to consider unorthodox governance options for geoengineering. Michaelson (1998) writes that global political dialogue and consensus will likely be more important than “adjudicative proceedings” and treaty-making for the development of geoengineering governance. Discourse must precede governance. Yet some form of formal arrangement to coordinate the actions and dialogue of all the actors on the international stage will one day be needed. It is time to start thinking more specifically about who we should entrust with the task of governing geoengineering, and what a geoengineering regime should look like.

3. GOVERNANCE PATHWAYS

3.1. Expanding the discourse

The discussion about geoengineering governance has been preoccupied with the theoretical foundations of governance, its moral and ethical challenges, and the looming shadow of unilateralism. To the extent that it has grappled with more practical aspects of geoengineering governance, it has been to review a few extant global institutions and frameworks that may have or should have jurisdiction over geoengineering (Bodansky, 1996; Lin, 2009; Virgoe, 2009). “The fundamental challenge posed by [geoengineering],” writes Barrett (2008, p. 45), “is not free riding but governance: who should decide if and under what circumstances geoengineering should be used?” That is by and large where the issue stands. Important past efforts have assessed whether and how geoengineering could become a subject of international law and regulations. A logical next step in geoengineering governance research would be to start evaluating potential governance arrangements for geoengineering, a task to which most of this section is dedicated. Before it goes on to discuss practical options, however, it first makes a few theoretical observations about geoengineering governance, and it presents its own list of criteria by which potential geoengineering regimes should be assessed.

This paper agrees with Victor (2008) that it is too soon to try to foist an extensive, binding geoengineering treaty on the world—that would surely have only one outcome at this stage: a moratorium. There is a danger that in the current governance vacuum, international environmental governance regimes will adopt legislation based on their narrow, conservation-oriented mandates. The CBD (2008) and the London Convention (IMO, 2008) are the two environmental conservation regimes that so far have moved to restrict ocean fertilization

geoengineering, as pointed out in the literature review. This regulates the issue by proxy, on a piecemeal basis and in limited fashion, by more or less self-appointed regulators with conservation mandates, taking action against what they see as a potential threat against their area of conservation. The central problem in this approach is that the only consideration given to geoengineering is a parochial and narrow focus on its potential side-effects; what cannot take place inside regulatory bodies like the Conference of the Parties to the London Convention is any holistic consideration of the issue.

The issue is too important and too complex to be left to haphazard and piecemeal governance solutions. While it is too early to call the adoption of geoengineering by two organizations a trend, it could easily become one if suspicion against geoengineering becomes the dominant sentiment in the discourse. But the state of climate science and geoengineering research—although in rapid development—is not yet complete enough that we can anticipate exactly what we need to regulate, nor is our understanding of the climate system complete enough that we can appreciate exactly what kind of geoengineering offers the best outcomes or whether it ultimately will do more good than harm. What is needed is careful evaluation of different governance options, with the goal of identifying possible governance pathways to cover different eventualities. Multiple avenues for governance could provide the necessary flexibility and resilience for dealing with geoengineering and dangerous climate change.

As sketched out previously, geoengineering is a rather vague label for a diverse set of options that aims to affect different aspects of the planet's environment for different ends. An important qualification that has not been emphasized elsewhere is the fact that not all geoengineering schemes are born equal, and the implications this bears for governance. SRM and GHG

remediation based geoengineering are radically different and will almost certainly require different control structures. The first is a short-term band-aid, palliative care for the Earth, a last resort to dangerous climate change; the other is a long-term solution that would be required in order to reduce the level of CO₂ in the atmosphere to a safe level—perhaps 350 parts per million (ppm) or lower, which has been proposed as the maximum safe level (Hansen et al., 2008).

“Bluntly, whose hands will be allowed on the thermostat?” Victor asks (2008, p. 330). A CO₂ loading of around 350ppm may be a safe level, but is it the right level? How warm should our planet be? As a long-term question dependent more on socio-economic tradeoffs and global justice than uncertainty and risk, it may be more amenable to a solution through a consensus-based treaty. Losers can be compensated (Jamieson, 1996). The question of what the long-term, ideal atmospheric CO₂ loading is (if there is such a thing) can probably afford to wait, as we have yet to see whether we can manage emissions, and the technology to remove CO₂ directly from the air is still on the drawing board (Keith et al., 2006; Lackner & Brennan, 2009).

SRM governance as well as ocean fertilization regulation may be required far sooner, however, and it has been added to the ever-growing gyre of unresolved global issues. The question is whether global governance has the facilities and the capacity to deal with the issue at this moment. Researchers allude to a dangerous governance gap opening up “between global issues and the capacity of traditional institutions to solve them.” (Rischard, 2001, p. 507) A group of scientists raise the alarm about how a number of global drivers create increasingly unwanted outcomes and converging crises that global politics have been unable to resolve, such as climate change, overfishing and increasing antibiotic resistance (Walker et al., 2009). Notwithstanding tremendous advances in the width and depth of global governance during the last few decades,

mounting challenges are overwhelming the capacity of global governance. Walker et al. point to sovereignty as the main culprit standing in the way of effective resolution of global issues: a provider of efficient domestic governance, but poor global governance. On the global level, they claim that sovereignty leads to partial solutions at best, undermined by international competition and sovereign recalcitrance.

Sovereignty also means that some nations may be concerned about the implications of geoengineering for their own security—hence, probably, some of the focus on unilateralism. As discussed above, implementing a geoengineering scheme such as a stratospheric sunshield may neither be expensive nor technologically difficult. Using off-the-shelf industrial and military technology, the world's militaries could undoubtedly use geoengineering offensively even today, through for example sending aircraft capable of high altitudes aloft to disperse SO₂ in the stratosphere (Robock, Marquardt, Kravitz, & Stenchikov, 2009). This has triggered fears that “rogue” nations might defy the world opinion and perhaps international law, in a desperate bid for survival or even out of mischief. With apocalyptic foresight, Cascio (2008) declared in the magazine *Foreign Policy* that “it’s only a matter of time before the world’s militaries learn to wield the planet itself as a weapon.”

Though Cascio’s (2008) opinion piece was undoubtedly meant to be controversial, we should be concerned about the realist preoccupation with unilateral geoengineering and the narrow focus on national security in the midst of the geoengineering debate. The observation that geoengineering could be carried out by a single actor does not automatically translate into the reality of rogue nations using it for nefarious purposes. Lots of technologies exist that could be used offensively, many of which are considerably cheaper and less complicated to operate,

demanding less dedication and delivering more predictable outcomes. Atomic bomb technology, for example, has proven to be relatively easy for a determined nation to acquire, despite non-proliferation efforts, yet most nations have refrained from doing so. Conventional weapons of every flavour are even more readily available. While stratospheric geoengineering may be inexpensive relative to mitigation, its costs would still run in the billions of dollars, and it would require a non-negligible commitment in terms of time and equipment—all the while delivering indiscriminate cooling and disruption of weather patterns (Robock et al., 2009; Robock, Oman, & Stenchikov, 2008). As such, it could affect the attacker just as much as the target of the attack.

3.2. Three virtues to ask of any geoengineering regime

Although this paper aims to expand the discourse beyond the theoretical, it is helpful to have some idea of what characteristics a geoengineering regime should exhibit. Before this paper examines governance alternatives, it will therefore first paint a picture of what a geoengineering regime should look like: an “ideal type”. Obviously, there are other traits that we might demand from the regime than those are listed here; Carlin’s (2006b, pp. 9-12) list, for example, addresses political rather than environmental factors.

This paper is content with three, broad characteristics that will speak to what considerations a regime must take into account in order to deal effectively and successfully with the problem. Elements of these characteristics are mentioned in the extant literature, but are expanded upon here, and presented in a coherent manner. These characteristics, this paper argues, must be cornerstones in any geoengineering regime. They span the gamut from environmental to political factors. The first—holism—speaks entirely to the environmental factors present and the goals of a geoengineering regime. The second—adaptability—speaks to how politics and science could

be managed to achieve optimum outcomes. The third—legitimacy—speaks entirely to the difficult politics of geoengineering governance.

3.2.1. It should be holistic

This paper puts the need for effective environmental outcomes ahead of political factors. Humanity depends on the Earth system—it is essential that we become good environmental stewards. This means a geoengineering or climate governance regime must take a holistic approach.

Holism entails more than merely comprehensiveness or completeness—it entreats us to perceive the whole Earth system as the subject of our actions rather than just one specific issue-area, such as the atmosphere (Kirchner, 2003; Kotchen & O. R. Young, 2007; Lovelock, 1990; Pitman, 2005; Schneider, 2001). According to Pitman (2005, p. 138), “Earth System Science is the study of the Earth as a single, integrated physical and social system;” it is multi-disciplinary, and it emphasizes the reflexive and interdependent relationship between different parts of the Earth’s environment (Clifford & Richards, 2005; Kotchen & O. R. Young, 2007; Schellnhuber, 1999; Schellnhuber, Crutzen, & Clark, 2005). James Lovelock (2008, 1990) likens the Earth to a living organism rather than a purely mechanical thing; it is more than just the sum of its parts, and it behaves in complex ways. When it comes to geoengineering and the risk of abrupt climate change, critical features of the complex Earth system—emergent properties, self-organizing behaviour, feedbacks and discontinuities—are precisely what we are concerned about, because they are central features in the workings of the climate system (Alley et al., 2003; Hansen et al., 2007; Lenton et al., 2008; Pitman, 2005; Schellnhuber, 1999; Schneider, 2001).

We should also be concerned about the tight coupling between social and biogeophysical systems, which means that even small perturbations in the climate system can engender cascading repercussions through other physical and social systems, because there is often little or no capacity to adapt to or absorb exogenous change (Kotchen & O. R. Young, 2007; Schellnhuber et al., 2005). The tight connection between different systems imply that there must be global agency to deal with the problem in a holistic manner—problems cannot be managed separately, without consideration of either causes or effects emanating outside a narrowly defined area. To that end, a 2009 article in *Nature* called for the creation of a governance council with responsibility for the whole of the Earth’s “critical zone”—essentially the lower atmosphere and the biosphere—to monitor and manage all the intricate environmental issues holistically (Richter & Mobley, 2009).

Stratospheric geoengineering would have an extensive impact on the Earth system, and has been associated with a high risk of perturbations and side-effects (Robock, 2008). Yet the intricacies of the Earth system also means that there are more and far subtler pathways for affecting the climate than CO₂ emission reductions, through the manipulation of complex feedbacks involving ecosystems, albedo change and GHG sinks (Chapin, Randerson, McGuire, Foley, & Field, 2008). In the interest of increasing resilience, holistic climate governance should not ignore these options. A regime should also consider other rapid remedial options such as mitigation of black carbon (soot) and ozone, which are responsible for a fair share of global warming (MacCracken, 2009; Ramanathan & Carmichael, 2008; Wallack & Ramanathan, 2009). On a different note, there should be degree of separation between the entity authorizing a climate intervention and the agent charged with its implementation. If the international institution charged with geoengineering governance were to attain operational capabilities, it may be that it would

become too vested in the particular technological solution that is chosen—by way of sunk costs, inertia, institutional culture or other elements—to retain a holistic perspective.

3.2.2. It should be adaptive

Virgoe (2009) makes an important point: that the uncertainty about how various geoengineering schemes would affect the Earth system and their potential for debilitating side-effects would make any climate intervention highly experimental. He calls for geoengineering governance techniques to embrace adaptive management techniques, enabling decision-makers to deal with unforeseen circumstances and changing conditions. Adaptive management is closely related to Earth systems science, exploring how complex biogeophysical systems can be managed or governed (Cooney & Lang, 2007; Folke et al., 2002; Gunderson, 1999; Holling, 1978). As Lin (2009) points out, adaptive management may also have significant political advantages, helping us overcome the debilitating consensus problem in global politics. As continuous adjustment brings many small changes rather than a few big ones, the stakes at each junction would presumably be much lower, especially since each decision could be revisited (Folke et al., 2002; Gunderson, 1999).

This paper stresses the need for an adaptive approach, and argues that it needs to be a corner stone in geoengineering governance, based on the combined reasoning of Lin (2009) and Virgoe (2009). First and foremost, a planetary governance regime charged with dealing with abrupt climate change would need the ability to make continuous and timely adjustments, and it would need to foster resilience—the capacity of both ecological and socio-political systems to tolerate disturbance (Cooney & Lang, 2007; Folke et al., 2002; Gunderson, 1999; Holling, 1978). There are, however, different ways of reaching that goal; post-normal science, for example, suggests

alternative avenues (Etkin & Ho, 2007; Funtowicz & Ravetz, 1993, 1999; Healy, 1999; Ravetz, 1999). Adaptive management has constraints that could prevent it from working when applied to the international arena, as pointed out by Thompson (2006). Weaknesses include dependence on centralization and top-down management, which may not go over well with nation states fretful over seeing their own authority decline relative to that of transnational and supranational entities.

The demand for adherence to decrees coming from the top of the hierarchy reflects a requirement for consistent implementation of management decisions once they have been made (Cooney & Lang, 2007; Folke et al., 2002; Gunderson, 1999; Holling, 1978). The process of producing decisions itself, on the other hand, should be open, collaborative and flexible; adaptive management is as much a social as a scientific process. Folke et al (2002, p. 440) write that we should “create arenas for flexible collaboration and management of social-ecological systems,” to be part of a rich fabric of multi-level governance. Involving stakeholders in governance can increase resilience not only through creating a diverse set of management options for crisis response, but also through strengthening awareness of the interdependence of the biosphere and humanity. Post-normal science recommends similar measures, with a particular focus on augmenting the process of knowledge creation (Etkin & Ho, 2007; Funtowicz & Ravetz, 1993, 1999; Healy, 1999; Ravetz, 1999). In the case of climate change mitigation, imposing solutions top-down has not been very successful, in part, it has been argued, because of widely disparate perceptions of risk (Etkin & Ho, 2007; Kahan, 2010). Including a wider array of societal stakeholders in the process of knowledge creation could therefore not only enhance its legitimacy and quality—for example through the inclusion of local knowledge and observations—but also increase the understanding of the participants of the inherent risks and uncertainties involved.

The global governance of geoengineering must be approached with a nimble attitude, as it will be an experiment in itself. When that is said, it is easier to proscribe the inclusion of more societal stakeholders in geoengineering governance than devising a way of doing so. There are no “silver bullet” solutions. One suggestion is that the creation of a geoengineering governance space should be incremental rather than sweeping, like adaptive management itself. This would further be consistent with the development of global governance, which, though once the sole domain of states, through decades of disorganized and organic growth has become a vast and heterogeneous space of tens of thousands of actors—what John Ruggie (2004) calls the “global public domain.” This paper does not suggest that the “invisible hand” of classical economic theory can be a good steward of geoengineering governance on its own, but that the solution probably lies somewhere in-between market mechanisms and overt, top-down and virtually unchangeable international treaties. The point is not that adaptive management necessarily has to become the governance tool for climate change and geoengineering, but that the governance of these issues is flexible and adaptive.

3.2.3. It should be legitimate

Beyond being effective at its given task—or perhaps in order to *be* effective—geoengineering or climate regime must also be politically viable (Bodansky, 1996; Carlin, 2006a; The Royal Society, 2009; Victor, 2008), and for that it must balance on the razor’s edge, with different aspects of legitimacy, accountability and democratic values on one side, and parochial, narrow-minded interests on the other. Because of the global but highly inequitable impact of geoengineering—particularly with schemes that affect radiative forcing—and the cosmopolitan values that infuse the transnational space, it is vital that an emerging regime is considered legitimate. Yet the inherent contradiction between these two factors likely mean that achieving

legitimacy will be extraordinarily difficult. For a global geoengineering or climate regime, the challenge of legitimacy thus looks daunting: who gets to decide, and how? Should it be under completely open and democratic control, or is it better left with a technocratic, “benevolent dictator?”

This is a familiar argument on the global governance arena, where critics have long pointed out the dearth of democratic control and accountability mechanisms (Glenn, 2008; Grant & Keohane, 2005). At the other extreme, however, are questions about to what extent global institutions should be hostage to the whims of populism and the demands of stragglers, as in multilateral treaty-making. According to Hurd (2007, p. 30), legitimacy is simply “the belief by an actor that a rule or institution ought to be obeyed,” and does not necessitate any form of participation—stakeholders often accept alternatives. Non-state stakeholders may thus perceive mechanisms such as increased transparency as a reasonable and acceptable substitute for participation, while nation-states may make utilitarian calculations that promises of “favourable outcomes” are an acceptable trade-off. In the words of Hurd (2007, p. 67), “states accept as legitimate those international laws and institutions that generate outcomes from which they stand to benefit.” But while outcome legitimacy and accountability substitutes may be palatable when the stakes and uncertainty about outcomes are low—under conditions of normal science—it may not be acceptable under the conditions offered by climate change, with questions of great uncertainty, irreducible risk and difficult trade-offs are on the table—especially if some of those liable to be worst affected may be disenfranchised.

For Schelling (1996), collective action on geoengineering is infinitely simpler than on climate change, since implementation can be left to only a handful of actors, but that is only half the

story. If stratospheric geoengineering or any other form of SRM were to be implemented, the mitigation would have to be ramped up considerably to minimize the scope and length of the intervention and to halt the acidification of the oceans, as well as to minimize the impact of other side-effects. Schelling further does not engage with questions of justice and fairness, which might implicate the need for a compensation scheme, discussed by Jamieson (1996) and Barrett (2008). Yet, as we invent new solutions to new problems, we inevitably create new challenges. If geoengineering winners were to compensate geoengineering losers after the principle of Pareto efficiency, as suggested by Jamieson (1996), it is easy to imagine how it would quickly become a highly controversial issue. How should the compensations be calculated and how would we ensure it reached the right recipients? What if, for example, climate change loser Indonesia benefits from geoengineering while climate change winner Canada loses? Presumably, Canada will still be the richer of the two in relative terms. Should geoengineering winner Indonesia compensate geoengineering loser Canada?⁴

The danger lurking behind the challenge of legitimacy is that if the world fails to come together around an agreement that promises to deal effectively with abrupt climate change—or if the agreement forswears any kind of geoengineering as a solution—self-preservation may push some countries to act unilaterally. Decisions in democracies are typically made by simple majority rule, but if they are not fair, are they truly legitimate? Is it legitimate if it is Pareto efficient, but not decided democratically? These are some of the challenges with which would-be geoengineering governors must grapple.

⁴ On the premise that Canada stands to gain from climate change, through increased agricultural productivity and the opening up of previously ice-covered areas (Borgerson, 2009; Cline, 2007) .

3.3. Governance pathways and frameworks for geoengineering

With the yardsticks just presented, the discussion now shifts to practical considerations in the sphere of global governance. Along the way, it assesses each alternative against the standards sketched out above. The goal of this section is not to compile an exhaustive list of all possible governance alternatives, but rather to examine some of the more likely ones.

3.3.1. Composite governance

As discussed above, in the absence of any other initiatives, global regulatory bodies have started to fill the vacuum by addressing aspects of geoengineering that fall within their purview. We might call this approach “composite governance.” It is the current mode of governance for geoengineering, as the CBD (2008) and the London Convention (International Maritime Organization [IMO], 2008) are the only international bodies that have adopted resolutions that explicitly mention geoengineering. In addition, scholars speculate whether other, conservation-oriented international regimes such as the Atlantic Treaty or LRTAP could regulate geoengineering activities (Bodansky, 1996; The Royal Society, 2009), which would further fragment the governance space.

Without any higher-level overtures to create a more comprehensive governance regime, this piecemeal accumulation of governance by self-appointed regulators seems poised to continue and be the only international regulation for the time being. For the reasons discussed in the literature review, it is too early yet to speak of a comprehensive regime, but given the current fragmentation of governance and the focus on the deleterious side-effects of geoengineering, the risk that geoengineering deployment and research will be banned increases. The decade-long taboo on geoengineering in scientific circles gives global environmental institutions, guardians of

the global commons and common pool resources, a strong mandate to impose moratoriums on geoengineering activities (Cicerone, 2006).

Naturally, the point is not that conservation is not important, or that geoengineering researchers should be allowed to run rough-shed over international anti-pollution and conservation treaties. However well-meaning, scientists and private sector companies hoping to generate carbon credits should not be allowed to roam the seas and conduct large-scale experiments unchecked. Countries should be careful with experiments that could cause transboundary harm.

Presently, rules for geoengineering research therefore seem to be a more pressing need than regulation for full-scale deployment. Though an important first step, the public is unlikely to accept scientific self-regulation and ethical norms as an alternative to formal regulation (Morrow et al., 2009), especially in light of the controversy around the “LOHAFEX” mission in early 2009, when an Indian-German research project conducted large-scale field tests with iron fertilization despite vehement public protests and accusations that it violated the London Convention (Jordan, 2009; Strong, Chisholm, Miller, & Cullen, 2009). Geoengineering without oversight could quickly turn popular opinion against the whole field.

Consensus-based agreements, however, has so far failed to meet the challenge of global warming. Bodansky (1999) and Sand (2001) question whether they can provide the necessary tools for dealing with complex, interdependent environmental problems such as climate change. They write that international environmental governance on the whole requires reform to be able to cope with the governance challenges in a world where both national sovereignty and national borders are eroding, yet where effective international regulation is not filling the resulting

governance vacuum (Bodansky, 1999; Sand, 2001). Part of the reason for this, argues Sand (2001), is that supranational regimes, as opposed to inter-governmental ones, must look for new sources of legitimacy. When governments cede authority to international bodies, these bodies can no longer claim legitimacy based on the principle of democracy.

The main criticism of composite governance, however, remains its very parochial nature. In a longer time perspective, it is hard to see how a holistic geoengineering regime could emerge from the composite model, or indeed any governance that looks at geoengineering only in light of its potential side-effects. Recent efforts by conservation regimes offer only obstruction, not avenues for conducting experimentation or deciding on how we should prepare for catastrophic climate change.

3.3.2. Scientific governance

As an alternative to the fragmented governance offered by the status quo, geoengineering governance—like climate change governance—might become an issue for comprehensive scientific governance under the UN umbrella. Climate change is a problem that has come to our attention only because it has been raised by scientific communities, and it is still defined extensively in terms of biogeophysical changes to the Earth system (Dessai et al., 2004). We might think then that governance of the climate and of geoengineering would be best carried out by experts, or at the very least under the close guidance of the epistemic communities that defined the problem.

Thus, at first glance, scientific (or professional) governance offers many advantages. An epistemic community is defined as “a network of professionals with recognized expertise and

competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain or issue-area,” with shared beliefs about causality and shared notion of how things ought to be, along with a commitment to make them better (Haas, 1992, p. 3). As opposed to other societal stakeholders, epistemic communities have no material interest in the subject under study and for which they make policy recommendations. They further have an inherent understanding of the irreducible uncertainty that plague complex problems and the dangers inherent in the “wait and see” mentality when there is risk of irreversible damage but considerable time-lag between cause and effect.

Crafting a comprehensive scientific governance regime housed by the UN might therefore seem like the obvious “next step” in geoengineering governance. Yet the problems associated with this kind of multilateral approach are legion, and difficult to overcome (Bodansky, 1999; Ralston, 2009; Victor, 2008). The solutions to climate change driven by epistemic communities have further been criticized for being too narrowly focused on restricting CO₂ emissions according to targets and timetables, rather than devising diverse sets of response options that could increase the resilience of the process, including adaptation and focusing efforts where their marginal utility would be the highest (Helm, 2008; Prins & Rayner, 2007; Wallack & Ramanathan, 2009). The Kyoto Protocol was fashioned as a “silver bullet” approach, it has been argued, while silencing those that wanted a broader set of policy approaches (Prins & Rayner, 2007). Imposing dramatic and universal carbon emission cuts from the top suggests itself as the most direct way of dealing with global warming, but the fate of the Kyoto Protocol and the slow pace of the negotiations to craft a successor treaty indicate that this was and still is nigh on impossible politically.

According to the post-normal science approach, the failure of this approach should be attributed to the turbulent relationship between epistemic communities and the rest of society, as scientists' preferred solution—the “silver bullet” described above—was strongly resisted by substantial parts the rest of society (Etkin & Ho, 2007). The lesson from post-normal science is that however objectively sound the solution proposed by epistemic communities was, it required a certain understanding of the risks and uncertainties involved—an understanding that was often not shared by the wider public. Public confusion bred scepticism that was readily exploited by powerful commercial interests (Kahan, 2010; Kolk & Pinkse, 2007). The sweeping policy changes that scientists called for came to be seen as unfounded, invasive and illegitimate.

Researchers must resolve this communications failure, and learn how to engender appropriate perceptions of both risk and consequences (Nature, 2010; Etkin & Ho, 2007; Kahan, 2010). Post-normal science prescribes a new model of science-societal relations—an extended process of knowledge creation, including stakeholders from across society (Etkin & Ho, 2007; Funtowicz & Ravetz, 1993; Healy, 1999). The goal is not to make scientific facts subject to a plebiscite, but to find solutions to problems that cannot be solved by epistemic communities alone and in isolation from the rest of society. While science unequivocally states that global warming is both objectively real and anthropogenic, scientists cannot propose objective solutions to the long range of social problems that global warming imposes (Etkin & Ho, 2007). The goal of science is to create objective knowledge, but the post-normal perspective points out that in matters of high risk and high uncertainty, scientists cannot be the disinterested public servants we desire them to be; their scientific opinions are inevitably coloured by their values (Etkin & Ho, 2007; Funtowicz & Ravetz, 1993; Ravetz, 1999). Is, for example, the problem of climate change that humanity is *not doing enough* to control environmental variables to increase human welfare, or is

that we have already exerted *too much* influence on the global environment? The answer to that question implicates completely different solutions, and is more a question of values and the norms that govern our relationship to the environment around us than science (Etkin & Ho, 2007; Funtowicz & Ravetz, 1993, 1999; Healy, 1999; Ravetz, 1999).

Post-normal science therefore recommends that values should be made explicit, rather than suppressed (Etkin & Ho, 2007; Funtowicz & Ravetz, 1993; Ravetz, 1999). Kahan (2010), explains how cultural values are at the very heart of the matter of the climate change challenge, as they are often involved in making us prejudiced one way or another to complex, societal issues. “We need to learn more,” he says, referring to the global research community, “about how to present information in forms that are agreeable to culturally diverse groups, and how to structure debate so that it avoids cultural polarization.” (Kahan, 2010, p. 297) It is thus necessary that scientists not only become better at disclosing personal bias, but also in responding to the bias of others. There is a danger that the debate about geoengineering will become as polarized as the one about climate change in general. If epistemic communities want to facilitate the changes they think are necessary and the right attitude to geoengineering, it is not enough to flood society with scientific data and hope it speaks for itself. Hence, there is no question that we must improve the relationship between epistemic communities and the rest of society, but what, exactly, should it look like?

3.3.3. International financial institutions

The World Bank (more formally the International Bank for Reconstruction and Development) and the International Monetary Fund (IMF) are probably the most well-known international financial institutions (IFIs) (Peet, 2003). As international lending institutions, however,

regulation of climate change mitigation is generally an issue-area far outside of their remit. The World Bank has taken climate change seriously and has instituted lending programmes and other initiatives to foster sustainable development, but its role remains ancillary.⁵ As for the IMF, it lacks any comprehensive treatment of climate change, making the issue subordinate to economic concerns.⁶ They are first and foremost tools in the service of facilitating economic globalization, fostering economic development and proselytizing the virtues of free markets, deregulation and the other tenets of neoliberalism (Peet, 2003). The question, then, is why they should have anything to do with geoengineering. Why should even discuss the option?

A secret draft agreement revealed during the Copenhagen Climate Summit in December 2009, was to give the World Bank extensive control over climate change finance (Vidal, 2009). Though the deal was scrapped, it shows an attempt by the World Bank to wield influence over climate change mitigation. The IFIs are powerful organizations, with close ties to national governments and powerful economic interest groups (Peet, 2003). Given the huge impact the changing climate will likely have on the global economy (Ackerman & Stanton, 2008; Stern, 2007), the hostility of neoliberal interests to mitigation, and the very low price tag on geoengineering, they are probably not going to be disinterested. Geoengineering may appear to be an attractive alternative to these interests, who would otherwise have to absorb a significant part of the costs of mitigation (Michaelson, 1998; Virgoe, 2009).

⁵ The World Bank has an overview of its climate change initiatives; see <http://beta.worldbank.org/climatechange/> (Retrieved 10 December, 2009).

⁶ For an overview of the IMF's role with regard to climate change, see <http://www.imf.org/external/np/exr/facts/enviro.htm> (Retrieved 10 December, 2009).

As protectors of parochial commercial, financial and national interests, it can probably not be expected that they would take a “whole Earth” perspective on geoengineering, though more thorough, historical analysis is required to determine whether they have the capacity to be adaptable. Lack of legitimacy, however, may be the greatest shortcoming of the IFIs. Both have their headquarters in Washington, D.C. and have been heavily influenced by American political and academic networks since their inception, from which they have been infused with the neoliberal economic agenda that has been so contentious in much of the rest of the world (Chorev & Babb, 2009; Glenn, 2008; Peet, 2003). Though ostensibly democratic, representation in their governing bodies depends mainly on financial contributions, which greatly favours the industrialized Global North (Glenn, 2008; Peet, 2003). Despite little input legitimacy, some redemption could perhaps be found if their results justified their less-than-egalitarian governance, but in this area too the IFIs have a poor record (Glenn, 2008). Decades of austerity policies, slashed subsidies, welfare cut-backs, privatization and other “structural adjustment” measures from the neoliberal basket have largely failed to spur the development and economic growth they were supposed to. Instead, it is claimed that these policies have been a boon to Northern transnational companies and exporting industries.

Whether the IFIs have the necessary competence to design policies to counter-act dangerous climate change, potentially involving geoengineering, seems dubious. Were they to try to play an overt role in geoengineering governance, they would likely meet considerable resistance, as the World Bank did when it became known that it was behind a secret draft agreement at the Copenhagen Climate Summit in December, 2009 (Vidal, 2009). They do, however, wield extensive discursive, ideational and structural power. It would be irresponsible to ignore the IFIs as non-entities in the wider climate change discourse.

3.3.4. The G20

Virgoe (2009) posits that geoengineering could perhaps be managed by a consortium of countries. But whereas he mentions the possibility of creating a new specialised multilateral cooperation project with limited membership, one already exist with some characteristics that could make it into an effective geoengineering consortium: the G20.

Matters of global importance have long been discussed and decided upon in a small, private club of countries known as the G8 (and the G6/G7 before that). The G20, or “Group of 20”, sprang out of the G7 in 1999, and is a loose coalition of nineteen of the “most systemically important industrialized and developing economies” in the world, plus the European Union (EU) (G-20, 2009a). Its members are permanent, and are all among the largest countries in the world by a tally of their populations, geographic areas and economies. Together they constitute over 80 per cent of the world economy and all world trade, and two thirds of the world’s population (Beeson & Bell, 2009). Like the G8 and the G7 before it, the G20’s mandate is mainly in the area of economic cooperation and coordination, but it has included a number of the world’s emerging economies in the discussion. In September 2009, the G20 countries announced that they had designated the G20 as the “premier forum” for economic cooperation, supplanting the G8 (G-20, 2009c).

The G20 is therefore best understood as an economic forum—how could it become involved in geoengineering? First of all, we should consider that the G20, like the G7 before it, has started to pay attention to issues outside of finance and economics (G-20, 2009c). Despite its initial focus on economics, the G7 turned out to be a dynamic institution, increasingly putting issues on the agenda with sometimes only a tenuous connection to the economy, such as development,

security and climate change (Garavoglia & Padoan, 1994). The G20 looks set to follow in its tracks.

Yet the most salient reason for considering the G20 for geoengineering duties is that it represents a (relatively) new type of global governance that holds promise that it might be able to side-step the old problems of inefficiency (LeSage, 2007; Slaughter, 2004). The G20 has been described as a “global steering committee” (Shin & Eilperin, 2009) or “governance network”, lacking a secretariat or any sort of executive body (Beeson & Bell, 2009; Helleiner & Pagliari, 2008; LeSage, 2007; Pettis, 2009). It exists only as an agreement to discuss matters of global or shared importance, coordinate national policies and, from time to time, hammer out agreements and make public statements about their goals, effectively stacking the global agenda. It is an informal way of reaching consensus in private, rather than through difficult and public multilateral talks, and without being hampered by too many opinions that have to be converged and accommodated. Representing 19 of the wealthiest and most powerful states in the world, plus the EU, the G20 can lead by example, by coercion, and by hegemonic influence.

Breaking through the gridlock of multilateral governance, working outside of the ordinary power structures and communication channels of the UN system, and bypassing the UN bureaucracy, the idea is that the G20 can be a more nimble and adaptable organization. But that is not to say that it is a good forum for discussion of geoengineering. At first it would seem paradoxical that this organisation—which is little more than a web of diplomatic channels and a series of intergovernmental meetings—could become a geoengineering consortium. Being without a secretariat or any independent bureaucracy whatsoever, it relies solely on the resources of its members (Beeson & Bell, 2009; Helleiner & Pagliari, 2008; Pettis, 2009). That also means the

G20 has no formalized way of incorporating scientific knowledge and epistemic communities in its governance.

More troublesome is the question of legitimacy: would other countries, particularly in the Global South, agree that the G20 is a legitimate geoengineering authority? To some, the G20 is only Western hegemony by any other name; a mechanism for co-opting the major economies in the South into the global neoliberal economic system (Beeson & Bell, 2009), called a “diplomatic hub-and-spokes system with the G8 in the centre.” (LeSage, 2007, p. 359) In this narrow view, “the G-20 thus helps the United States and the G-7 dominate a wider order and legitimize a G-7 generated view of the world.”(Beeson & Bell, 2009, p. 71) Would other countries go along with a geoengineering mandate from the G20? As the G20 represents two thirds of humanity and is responsible for more than 80 per cent of all value creation (Beeson & Bell, 2009), another question is what the rest can do about it if they disagree.

The G20, however, is not quite ready to solve all the world’s problems. Though the scramble to respond to the global financial crisis of 2008 and 2009 shows that the G20 has considerable capacity for fast action, it also revealed a penchant for sweeping but broad statements followed by subsequent inaction (Pettis, 2009). Even a group of 20 members may be too big to be effective, representing too many diverse interests and having to accommodate the smallest common denominator.

3.3.5. The United Nations Security Council

With 192 member states, the UN may be closest thing we have to a world authority, making the Security Council the closest thing we have to a world government. The Security Council has

been described as “possibly the most powerful organization ever known to the world of states,” (Hurd, 2007, p. 12) vested, according to Article 24 of the UN Charter, with the “primary responsibility for the maintenance of international peace and security”—but that is also the whole rationale behind its existence, as it was never intended to be a world government. Indeed, its role remains strictly limited to matters of war and peace, according to Article 7, to wit, to “determine the existence of any threat to the peace, breach of the peace, or act of aggression” and to take military and non-military action to “restore international peace and security.”

Thus, if the Security Council wants to tackle geoengineering, it must first be constructed as a matter of international security. As chronicled previously, there have been developments in that direction, seen for example in the narrow focus on national security concerns with regards to unilateral geoengineering, as well as realist fears about the offensive possibilities inherent in various geoengineering technologies. There is also the increasing attention by security communities to climate change—if climate change itself has been extensively securitized at the time we encounter a climate emergency, it is reasonable to believe the same fate would befall geoengineering. Yet, good reasons for securitizing climate interventions at this early stage are few and far between, if they exist at all. Regarding the possibility that any of the handful of “rogue” nations of the world would somehow turn geoengineering into a weapon, such attempts should hardly be difficult to discover,⁷ and as a classical act of aggression, the Security Council would have a clear mandate to sanction the country and even authorize military reprisals. As for all the rest of the world’s nations, that they should wish to use geoengineering as a weapon seems like a notion divorced from reality and the work of an imagination used to seeing the

⁷ If we imagine that the rogue nation uses any of the possible delivery techniques listed by Robock et al. (2009).

world exclusively through a security lens. The geopolitics of geoengineering will be complicated enough without speculation of this kind.

How, then, could the Security Council be a governance framework tasked with evaluating whether, when and how a climate intervention should happen? Because of the Security Council's limited mandate, this would require the construction of dangerous climate change itself as the threat to world security—perhaps because of the risks to human security or the destabilizing effects of millions of people displaced by the shifting climate—with the option of not using geoengineering perceived as an unacceptable security risk. Of course, vesting the Security Council with the responsibility of evaluating and possibly authorizing the use of geoengineering does not mean that it will ultimately be used—perhaps their assessments will suggest that the risks of geoengineering do not justify its use, or that alternative methods such as rapid mitigation would be more appropriate.

If we encountered a climate emergency and the discussion about geoengineering was gridlocked, it appears likely that geoengineering would end up on the Security Council's agenda. An advantage of the Security Council is that it can react quickly to events and changing conditions. All countries have permanent representation on hand in the UN's headquarters in New York. The Security Council can also make snap decisions. Since efficiency and adaptability are paramount to geoengineering management, the Security Council may be close to ideal in that respect. Holistic management, however, is far from guaranteed when the issue gets elevated to the highest level of geopolitics.

There are obvious issues when it comes to legitimacy as well. According to Hurd (2007), legitimacy is what allows larger states to have their will. Yet, though the UN Charter technically lends the Security Council wide discretion in deciding how to safeguard the peace, it is not completely insulated from world opinion (Chan, 2003). This may modify its legitimacy—since legitimacy is a subjective perception—but not its legality, and probably not its resolve. The largest obstruction in the way of effective Security Council, however, will probably come from within rather than without, in the form of disagreement between the veto-wielding permanent members the Security Council, which can often prevent issues from even being raised (Hurd, 2007; Malone, 2004). These Permanent Five (P-5) could even prevent the condemnation of—and possibly authorisation of sanctions against—an unlawful geoengineer. Another possibility is that one of the P-5 chooses to geoengineer, knowing that it can do so with little fear of military reprisal or political sanctions—though other major international bodies like the General Assembly might react negatively.

Since the Cold War ended, the use of the veto has gone down considerably, indicating perhaps that the P5 have a more amicable relationship (Weiss & K. E. Young, 2005). Yet, it is also the case that most issues that would be vetoed never get to a vote, so we should probably not read too much into veto statistics. But even if the P5 did come to a consensus, in order to be effective, they must agree not only in principle, but to such an extent that they will put force behind their resolutions to generate compliance. Countries can choose to ignore the will of the Security Council if they believe it is merely posturing.

3.3.6. Novel forms of governance

It is, of course, possible that geoengineering governance is taken up by another organization not considered here. It is also possible that new organizations and governance structures can be created. As early as 1974, Kelloggs and Schneider (1974, p. 1170) discussed the potential for novel forms of geoengineering governance:

Perhaps we should consider the creation of a panel of "impartial" international experts to adjudicate (or at least mediate) such disputes before one explodes. It may be too late if a conflict were to occur first, with polarization and partisanship being an accepted factor in world diplomacy. How would power be assigned to such a panel? How would its constituency be determined? These questions are as familiar and nearly unanswerable as those that accompany any sort to share power and responsibility multinationally.

In 2001, Jean-François Rischard (2001), then a vice-president of the World Bank, suggested the creation of something similar, in the form of what he called "Global Issues Networks", as a possible solution to the increasing global governance impasse. Rischard envisions 20 global issues networks, each dealing with one critical global issue, from climate change to internet commerce. Rischard's networks would be radically different from other forms of governance, which he describes as fundamentally broken, and would not have legislative authority that could allow governments to compete for national advantage. Instead, each network would be a forum for creating and brokering the knowledge and norms that will be necessary to deal with the particular issue under its purview. These networks would be constituted by a diverse set of actors and their processes would be entirely open. They would wield power only through "rating" countries and actors on their performance within each given issue and relative to the norms that

have been crafted. In this sense they would not really be governing so much as provide a new, but more effective, discursive space for civil society—a new type of “quasi-non-governmental” organization, wielding influence through its reputational impact.

Such an arrangement would thus, in theory, go far in meeting the democratic ideal, and could enjoy a high degree of legitimacy. What more is, Rischard’s (2001) global issues networks could be highly flexible and adaptable. On the other hand, whether this can be a complete solution to all the governance challenges of geoengineering is doubtful—they would not have legislative powers and are clearly intended to complement global governance institutions rather than replace them. They create new channels for civil society to wield influence, but it also a dialogue between established powers and civil society. As such, they are very close to the extended peer communities of post-normal science.

4. GEOENGINEERING UNDER A CLIMATE EMERGENCY

4.1. Looming threats: what is a climate emergency?

Stratospheric geoengineering has, as aforementioned, been constructed as a remedial solution to catastrophic or abrupt climate change, sometimes called “climate emergencies” (Blackstock et al., 2009). The climate change literature is not lacking in physical descriptions of climate emergencies (Dessai et al., 2004). But how do we know if we are, at any given point in time, experiencing a climate emergency or about to go into one, and who is to alert us about it?

This section discusses the politics of climate emergencies and geoengineering. If the concept of geoengineering is to be a “last resort”, timing and presentation may be everything, but “last chances” may be easier to identify with the wisdom of hindsight. Asking who can define a

climate emergency further brings to the forefront again the issue of the role of epistemic communities in the public discourse and public policy under conditions of high risk and high uncertainty. Could or should climate experts make the decision that the circumstances are precarious enough that geoengineering ought to be used? The first part of this section discusses this question, building on the previous discussion of epistemic communities and post-normal science. The second part then discusses which of the organizations and frameworks analyzed above might lead us through a climate emergency. The third and final part uses path-dependency theory to analyze how events that occur today may affect how geoengineering comes to be constructed in governance and the public consciousness, and what it means for the prospect of countering a climate emergency with geoengineering.

The first problem with climate emergencies is language: conceivably, one could argue that we are already experiencing a climate emergency. By most accounts, only dramatic emission reductions can prevent the planet from experiencing potentially dangerous climate change and possible climate thresholds (K. Anderson & Bows, 2008; Hansen, 2006; Hansen et al., 2007; M. Meinshausen et al., 2009; Solomon et al., 2009). Even with dramatic emission reductions, we are on track to overshoot the official 2°C target set by the European Union (K. Anderson & Bows, 2008; Commission of the European Communities, 2007; M. Meinshausen et al., 2009). According to Prins and Rayner (2007, p. 974), the situation is so precarious that the world community should put investment in alternative energy sources on “a wartime footing,” a serious statement about the urgency of moving away from carbon fuels.

Yet, the essence of an emergency is something abrupt, defined in a dictionary as “a sudden, urgent, usually unexpected occurrence or occasion requiring immediate action.” (“Emergency,”

2009) However serious the potential consequences of climate change are, they are still fairly distant and not unexpected. Thus we see that the term “emergency” is less clear than it may have seemed at first glance. MacCracken, Moore and Topping Jr (2008) uses more precise language, labelling their threshold event “sudden and disruptive climate change,” thus sacrificing the social connotations of the word “emergency” for clarity, and avoiding at the same time any allegations of alarmism. They further introduce a second, important qualifier—climate change must also be disruptive—which demands that we ask, “to whom or what might it be disruptive?”

Researchers have suggested various definitions of abrupt climate change, which can generally be placed in one of two categories, depending on whether they are based on thresholds in physical or social vulnerability (Dessai et al., 2004). An example of a physical threshold could be the collapse of the West Antarctic ice sheet, while a social threshold could be the sudden onset of mass migration. Dessai et al. further distinguish between internal and external definitions; that is, dangerous climate change as identified by experts, observing the problem at a distance, and that which is experienced first hand by the population at large.

Much has been made of the potential for social unrest and even war triggered by ecological crises, with stories of horror and suffering popping up to capture the public imagination from time to time (e.g. Dyer, 2008; Kaplan, 1994). There is considerable risk that global warming may exacerbate or even trigger ecological crises, causing cascading effects through tightly coupled social systems (Herman & Treverton, 2009; Scheffran, 2008). Social thresholds such as war or migration, however, are unreliable gauges of environmental problems. There is not necessarily a clear causal relationship between exogenous factors like environmental degradation and social disruption. Homer-Dixon (1999) explains that causation can be extremely difficult to pin down

to either environmental or socio-political roots, owing to a large degree to the reflexive relationship between them. The idiosyncrasies of each situation further make generalization and extrapolation difficult. Not to mention that avoiding devastating social thresholds in the first place are assumed here to be the main goals of a geoengineering regime. Despite the tight coupling between social and physical systems, there is bound to be considerable lag time before observable effects take place in the social realm as a consequence of ecological change. When the situation has deteriorated to the point of triggering conflict, irreversible ecological damage may have occurred.

“To date,” Dessai et al. (2004, p. 19) write, “much of the information generated on environmental risk has ignored the first of these two types of information, and [focused] on a positivist approach based on natural science.” In other words, climate change and other environmental problems have been defined largely by outsiders in scientific language, an approach that has succeeded in constructing a range of environmental problems as serious and legitimate issues, but where earnest, concerted action is often lacking. According to the post-normal science approach, this internal definition is precisely what is often missing in environmental governance (Etkin & Ho, 2007; Funtowicz & Ravetz, 1993; Healy, 1999; Ravetz, 1999). Just as the apparent lack of connection between emitting CO₂ and experiencing climate change has hampered political support for mitigation, so it may be with abrupt climate change. Physical thresholds suggest themselves as the most reliable and logical gauges of whether abrupt climate change is on-going or imminent, but if abrupt climate change is exclusively presented by epistemic communities as a physical problem, it may not yet be a lived experience for most people and thus not perceived as a legitimate crisis.

Effective action under a climate emergency will thus most likely require an internal as well as an external definition of danger, which again confirms the argument that geoengineering is in all aspects post-normal. Garnering political and social support for radical interventions into the Earth's delicate climate system without obvious signs that the consequences of inaction might be dire indeed could be extremely difficult. The lesson of post-normal science is that extended peer communities are essential participants in the management and governance of environmental problems with high risk and high uncertainty.

4.2. Responding to abrupt climate change

Since we do not know if, when or how a climate change may occur, and whom we shall entrust with bringing us the ill tidings, predicting who could lead us through a global climate emergency can only be speculative. Section 3 analyzed six potential governance frameworks for geoengineering, though they are hardly equal in terms of power and authority. Moreover, a multilateral geoengineering treaty is still a possibility, as is successful climate change mitigation, and we may have decades yet to explore new kinds of governance. Given the tremendous pace of globalization and the deluge of new global governance arrangements over the past 30 to 40 years, we can hardly anticipate what will happen in the future. The geopolitical situation is also changing, as the old and established “great powers” are being challenged by large and populous “emerging powers” like China, India and Brazil.

Nevertheless, we can still attempt some analysis based on the current geopolitical situation. The G20 assumed authority to handle the the 2008–2009 economic and financial melt-down (Helleiner & Pagliari, 2009), pushing aside the IFIs that had played a very active role during the Asian financial crisis of 1997. The G20 acted in an unprecedented way by taking charge in the

financial crisis, meeting for the first time at the leaders' level in Washington, D.C., in November 2008, and then twice more within a year (G-20, 2009b, 2009c; Helleiner & Pagliari, 2009). Though their actions have been criticized for falling short of what was needed, and for their failure to prevent countries from enacting protectionist policies,, they acted decisively in pledging resources to arrest the crisis (Helleiner & Pagliari, 2008; Pettis, 2009; Suominen, 2009). Yet, beyond a doubt, the financial crisis has been a time of tremendous learning for this young organization, and the G20 demonstrated that its “networked” governance structure could work. What more is, the G20 now has experience with rapid, concerted action.

Of course, close analogies to abrupt climate change do not exist—the 2008 financial crisis hardly compares. Nevertheless, the G20 has ascended to the very forefront of geopolitics since its inception in 1999, and could very well develop into a global geoengineering authority. The prospect of abrupt climate change poses a significant threat to the G20 countries, providing a serious incentive to act if other avenues of regulation fail, or if the world opinion turns against geoengineering. In that case, perhaps we would see the climate emergency framed as an economic disaster, with geoengineering as the most cost-effective solution. Before they can do that, however, the G20 must overcome its internal differences. The financial crisis amply demonstrated that coordinating the different preferences, policies and philosophical outlooks of 20 members, each with their own domestic agendas, was no easy task (Pettis, 2009; Suominen, 2009).

The other obvious candidate for assuming geoengineering authority is the Security Council. We do not have an Environmental Security Council, or a “Critical Zone Council”, or any other council that can respond to global environmental emergencies—only threats to international

peace and security have been considered critical enough to have an authoritative global council. Centuries of debilitating war between the European powers, culminating in two devastating world wars, were very good reasons to focus on security as the main threat for international society, but today, the Earth itself and the environmental conditions that facilitated the rise of humanity are in danger. Barring the unforeseen creation of an abrupt climate change treaty or something similar giving an executive body *carte blanche* to do whatever is necessary, the Security Council, as the pinnacle of world authority, is likely the closest thing we will get to an environmental council.

The security implications of climate change were elevated to the Security Council for debate for the first time in 2007, and predictably sparked debate between countries that welcomed the debate and those that opposed it (United Nations Security Council, 2007). The Security Council would probably need a legitimate reason before it could exercise authority over the issue of climate change, such as the fear of and the possibility of unilateral geoengineering or the potential for severe ecological degradation and sea-level rise following a climate discontinuity. Disagreement between the P5, however, would likely be the greatest obstacle to the adoption of climate change or geoengineering by the Security Council, particularly since the P5 are all prominent members of the G20. Should they want to, they could reserve the issue of geoengineering for the G20.

4.3. Different governance paths, different outcomes

Whatever governance route we embark on, it will probably not be any of the “ideal types” outlined above. Political leaders rarely have the luxury of sitting down together to pick a governance solution *a la carte*, from the above list or any other, regardless of what might be the

“best” option. Instead, what political solutions are viable are often determined by past events, as well as developments in other areas of society. In addition to this comes the possibility of stochastic events and exogenous factors that can change the political landscape completely, as it did on 11 September, 2001, making the previously unthinkable thinkable and vice versa.

Individual behaviour is shaped by countless factors, but in general, there is often considerable feedback or reflexivity between decisions and outcomes—“policies produce politics” (Pierson, 1993, p. 597)—which adds a layer of complexity to political systems. As discussed in the literature review, the fate of political processes can be determined entirely by decisions made at critical junctures in time, seemingly inconspicuous events or decision that come to exert inordinate influence on later decisions. Under the initial conditions, many different outcomes may be possible, folding out like branches on a tree. Subsequent decisions then become subject to “lock-in”, moving down one particular branch, and carry a high break-out cost: when the machine of governance is set down a particular path, it may not be easily turned aside nor down alternative paths should the attempted path prove unserviceable. Like the Titanic, global governance is slow to set in motion and slow to stop or turn—and there may very well be proverbial icebergs ahead—catastrophes waiting to happen. Knowing when we are standing at a critical cross-road, however, can be nigh impossible, since small events can have large consequences.

There is thus good reason to think about the impact of path-dependence on geoengineering governance at this point, almost at the “beginning of history”, as it were—although the climate change mitigation regime means it is far from a clean slate. But since this is probably the formative moment of geoengineering regulation, we should pay close attention to how it unfolds.

We do not know when a critical juncture in governance will occur, but conceivably, the collective impact of global commons regulators banning geoengineering might be such a juncture—in which case we may already be heading down a path where geoengineering options are foreclosed. The world may at this point be choosing to go down the seemingly safe route of banning geoengineering, the research of the subject, and all mention of it, for fear that the moral hazard it presents could corrupt mitigation efforts. As Lin (2009) argues, a ban on geoengineering should be the baseline, since we can always re-evaluate later. Yet, instituting a ban at this point could have the effect that it emboldens opponents of geoengineering, further amplifying calls for tighter and tighter regulation, making the path self-reinforcing. In a similar vein, ENMOD, the security framework for weather modification, may not be the appropriate vehicle geoengineering governance, as suggested by Lin (2009). Associating geoengineering with a treaty focusing on security and militarization of technology with chiefly peaceful applications could end up strengthening the case that geoengineering is a threat to global security, persuading people that geoengineering is indeed too dangerous to implement.

Anti-geoengineering sentiments are not eased by the actions enterprising people that have spied opportunities to profit from geoengineering—specifically to create carbon credits from ocean sequestration of CO₂ by way of iron fertilization (Rayfuse et al., 2008; Strong et al., 2009). Human enterprise and ingenuity surely has a place in solving the CO₂ problem, and market-based solutions may have a place too (as long as they work), but at a moment when geoengineering is being constructed in the public consciousness, engaging in controversial behaviour is ill-advised. The attempts of one company, Planktos, at conducting private experiments with iron fertilization predictably brought considerable public ire (Rayfuse et al., 2008). That is not to say that the implementation of a particular climate intervention could not be

outsourced at a later date, as hinted by Carlin (2006b) or Michaelson (1998), but attempting to commercialize geoengineering technology before it has been accepted by the broader public might do harm to the entire prospect of geoengineering.

Given the risk of creating momentum behind anti-geoengineering sentiments, it is particularly important that commercial enterprises as well as epistemic communities do not bring public wrath down on them by running unauthorized research missions, perhaps becoming “the straw to break the camel’s back”—triggering a critical juncture. Though it was ultimately deemed legal under international law, the LOHAFEX scientific experiment referenced above ran a similar risk, perhaps by not doing enough to assuage a nervous public (Strong et al., 2009). Research efforts must continue, so scientists will have to redouble their efforts in convincing the public of the importance of their mission. If anti-geoengineering sentiments were to lead to insufficient research, it may create lock-in too strong to overcome, since, if a climate emergency does occur, opponents will essentially be right when they claim the technology is too uncertain and unproven. In a worst-case scenario, writes Pierson (1993, p. 609), lock-in can lead to depoliticization of the issue: “By accelerating the momentum behind one policy path, they render previously viable alternatives implausible.”

Regulating geoengineering under the UNFCCC is a strong possibility, since there have been several calls for this (Barrett, 2008; Lin, 2009). If the UNFCCC were to be given comprehensive authority, also over areas nominally belonging to other regimes such as UNCLOS or the London Convention, it would remove the current governance vacuum that has allowed these regimes to assume authority. If we do attempt to regulate geoengineering under the UNFCCC umbrella, however, we cannot afford that it becomes a competition ground for a new round of sparring

between states motivated by self-interest, or becomes mired in even more layers of bureaucracy. That way too, lays peril. Consider the path of business-as-usual in climate change mitigation—if around 2015 is the deadline for starting a downwards CO₂ emission trend if we want to avoid dangerous climate change (K. Anderson & Bows, 2008), then the negotiations over the Kyoto successor might be a critical juncture. Either the world agrees to cut emissions dramatically by 2020 and more thereafter, or we plunge headlong down the path of no return towards dangerous climate change.

5. UNILATERAL GEOENGINEERING

5.1. Unilateralism and the case of a missing global consensus

One of the chief concerns of geoengineering researchers appears to be a worry that single actors may use the technology without consultation or heed of the rest of the world (Keith, 2000a; Lawrence, 2006; Lin, 2009; Victor, 2008; Virgoe, 2009). Somehow, unilateral geoengineering appears to have become one of the greatest political fears of the geoengineering discourse. This paper argues that this focus is unfortunate. As was mentioned in the literature review and discussed further in Section 3 and 4, focusing on unilateralism could allow national security establishments to get an angle on geoengineering, as they have through the attempts to securitize climate change, but why would this marginal possibility so scare researchers? Has the fear over unilateral geoengineering perhaps been a bit overblown? Perhaps researchers fear the consequences of heading down the wrong path more than unilateralism as such.

Section 3 and 4 asked whether the G20 could be a geoengineering consortium. Gwynne Dyer (2008), writing in fictional form about unilateral geoengineering in the future, speculates that

such a consortium could also be a group of poor countries from the Global South suffering under the onslaught of climate change and frustrated by the dithering of the rich industrialised North. In Dyer's dystopian account, Indonesia and the Philippines, bankrolled by China, become the geoengineers. Opponents of geoengineering have completely shut down the debate around the issue, paralyzing action in the rich, industrialized world even as the mercury creeps into dangerous territory and the Global South suffers under the onslaught of climate change. Geoengineering, it turns out, is politically toxic and too dangerous to discuss. In the vacuum that is left, a few countries in the South feel they have no option but to act.

Events could very well transpire in this way if we go down the wrong path. Victor (2008, note 14) singles out Australia, Brazil, China, India, the EU ("if it could agree to act as one"), Russia, and Japan as possible geoengineers, based on certain prerequisites such as logistics and a large territory. It is worth asking, also, whether we should consider action by strictly limited multilateral (or minilateral) organizations such as the G20 or the EU unilateral if lacks global consent? What then, if a group of countries from the Global South unite, representing, for example, 50 per cent or more of the global population, but none of the industrialized nations of the Global North? Though such a large consortium would be difficult to assemble, China and India together have approximately 2.5 billion people, or roughly 40 per cent of the world's population.⁸ If we add Bangladesh, Brazil, Indonesia, Pakistan and Nigeria, they represent about half the world's population, and a large number of those that can be expected to suffer the most from climate change (P. Gregory, Ingram, & Brklacich, 2005; Mertz, 2009; Parry, Rosenzweig,

⁸ The calculations were made on the basis of data from the CIA World Factbook (Central Intelligence Agency, 2009a, 2009b).

& Livermore, 2005). At a certain size, the problems of multilateralism would make a cooperation project unmanageable, but how would the industrialized North react to a determined coalition of these countries?

5.2. The strategic dilemma of unilateral action

Given the vagaries of global governance, it might seem like the best option for each player is to build up their own capacity for geoengineering rather than waste time and resources to try to negotiate in an environment where the whole concept is anathema—plus, they may figure that it is better that the scheme is under national control anyway. A country could therefore think it is doing a favour to the rest of the world, which is dithering and unprepared. Barrett's (2008) logic is that any country for which the prospective benefits of geoengineering are greater than the costs would be willing to try it, should all other countries abstain. Here is the crux of a strategic dilemma, then: what happens if all these prospective geoengineers must make their decisions at the same time, not knowing the action of the other?

One way of approaching that dilemma is through game theory. Game theory cannot help us predict the future, or say whether unilateral geoengineering will occur, but it can help us understand the strategic choices different countries face when they must decide on geoengineering policy (Snyder & Diesing, 1977). Game theory is useful, because as they mull their options, countries try to anticipate what the positions of the other participants are going to be—what are they going to offer, where will they stand firm, where will they make concessions, what are their demands, and how will they react to *your* demands—and routinely base their decisions on their anticipations. Each player is assumed to be rational, acting to maximize pay-off while minimizing risk.

		B	
		Cooperate	Defect
A	Cooperate	3,3	1,4
	Defect	4,1	2,2

Table 1: Prisoner's Dilemma

		B	
		Cooperate	Defect
A	Cooperate	3,3	2,4
	Defect	4,2	1,1

Table 2: Chicken

		B	
		Cooperate	Defect
A	Cooperate	2,2	1,4
	Defect	4,1	3,3

Table 3: Deadlock

		B	
		Cooperate	Defect
A	Cooperate	2,3	1,4
	Defect	4,2	3,1

Table 4: Bully

The matrices above depict the different incentive structures of two players with two options.⁹ They are, of course, highly stylized, abstract and somewhat arbitrary, but the exercise is one of modelling rather than prediction. If the purpose was to make a more realistic representation of a climate emergency, we would probably have to introduce more dimensions to the matrices or use extensive form diagrams to capture the varying incentive structures of each player. We would also have to model the effects of sequential game-play, rather than just a single game. In this case, there are two players: A and B, short-hand for the Global North and Global South. They could also stand in for individual countries with similar incentive structures. Each player is motivated by the desire to maximize the pay-off to themselves, but the maximum, four, is only obtainable if the other player cooperates while you defect. At the same time, each wishes to

⁹ The game theoretic matrices in this paper have been borrowed from Snyder and Diesing (1977).

avoid the unacceptable and punishing pay-off of one. The least each player could accept is two, whereas three is the best outcome they can get if they both choose a cooperative stance.

The negotiations that led to the Kyoto Protocol have been characterized as a “Prisoner’s Dilemma” (Table 1): each country recognizes the problem but wants to avoid the costs of dealing with it (Hardin, 2008; Ralston, 2009; *The Economist*, 2007; Thompson, 2006). Despite the seriousness of the challenge, agreement on how to arrest climate change has been held up for years by free-riding and selfish behaviour. At the present time it is therefore tempting to think of the geopolitics of climate change through the game model “Chicken” (Table 2) rather than the Prisoner’s Dilemma. All countries are pressing for advantage while hoping for the others to yield—and no one has yet yielded or compromised, sending us presently straight towards the cliff. But it is also possible that for individual countries, the short-term economic advantages of no resolution—the effective result of the Kyoto Protocol—overshadow the long-term costs, making the game look like “Deadlock” (Table 3) to decision-makers. In this situation, all players perceive that they stand to gain more from defecting than from cooperating.

Yet, these simple representations belie a fundamental truth of global climate change and politics. The premise of the game models of the previous paragraph is that the situation is symmetric—that all players have the same incentives. But different countries are hardly equal in reputation, power, exposure to risk, and potential pay-off from climate change and the prevention thereof. In multilateral climate change negotiations, this has resulted in bitter stalemates and bickering over the responsibility of individual countries to tackle the problem, with reports of a widening chasm between Western countries and China coming in after the Copenhagen Climate Conference in 2009 (Cléménçon, 2008; *The Economist*, 2010; Thompson, 2006).

That leads us to the analysis of geoengineering through the lens of game theory, advertised as this section's main contribution to the discourse on unilateral geoengineering. Ultimately it is not very long. Instead it encourages further digestion, analysis and speculation by readers and other researchers looking at geoengineering politics.

Let us assume that at the time abrupt climate change suddenly sets in, global agency for rapid geoengineering does not exist, though both the North and the South has the technical know-how to implement it. Indeed, a good method of stratospheric geoengineering exists. In this future world, however, the North has gone down a path where geoengineering has become taboo and associated with a steep political cost. Continuing its tradition of short-sightedness and political expediency when the environment is pitted against the economy, the North further calculates that it is easier to deal with the fall-out of a climate emergency than its causes. The North can further be reasonably certain that it will not be as badly affected as the South, having a more robust economy, more effective governance (on the whole), better emergency response options and higher socio-ecological adaptive capacity (little or no subsistence farming, for example). In addition, some of the North's losses may be buoyed by increased agricultural productivity, shorter and warmer winters, and new shipping routes as well commercial opportunities in previously ice-covered areas (Borgerson, 2009; Cline, 2007).

The South, on the other hand, does not have that luxury. Poverty, poor governance, low adaptive capacity and even existential threats combine to make geoengineering a rather attractive proposition for the South. This game is thus modelled after the assumption that underlies the fear of unilateralism: existential threats may provide incentives for one country or consortium to go ahead with geoengineering alone rather than chance it and hope that the other player offers

cooperation. While cooperation in this situation would produce the largest aggregate welfare, both the North and the South would derive maximum individual utility from defecting—deciding to act unilaterally—while the other player chooses to cooperate. At the time of a climate emergency, they must therefore decide whether they want to signal that they want to cooperate, or attempt unilateral geoengineering.

But the North stands to lose more from defecting than from cooperating with or yielding to the South if the South also defects. The scenario that has been built above is best illustrated by the game “Bully” (Table 4), because only one party is really interested in geoengineering—the South—and would still benefit significantly even if both parties decided to act unilaterally. The South thus has every incentive to bully the North into submission. First of all, time is of the essence. Second, the decision to geoengineer is popular. Southern politicians calculate that is politically expedient to offer a home-grown solution to the problem of climate change, rather than to hope for cooperation from the North that may or may not materialize. After all, the North has had decades to reduce its emissions and foreclose the possibility of a climate emergency. By becoming a geoengineer, the South also retains control of all aspects of the project.

For their part, Northern politicians cannot roll out their own geoengineering scheme without incurring a heavy political penalty at home, given that the topic is anathema. Thus it is that the South could become the world’s self-designated and unchallenged geoengineer. But the North could also lose face by silently standing aside so Southern countries can experiment with the climate on a grand scale—while the inexorable logic of the 2x2 diagram (Table 4) dictates that the North ought to fold their cards, the South must still be careful not to overplay their hand. The North may defer the issue to the Security Council, but given the obstacles in the way of Security

Council action, the greater danger is that the North resorts to military action. If the Southern experiment goes wrong or is suspected of causing significant harm to Northern interests, the risk increases further, but as the American decision to invade Iraq in 2003 shows, stated reasons need not be objectively real (Pillar, 2006).

Could events unfold in the way just presented? It is, of course, a highly stylized and speculative scenario, and it only offers one interpretation of what might happen. In the future, decades hence, there is no telling what the military and political strength of the old world powers will be (including the United States, now graduated to the old world) relative to that of emerging nations. Victor (2008, p. 334) believes that if one country starts unilateral geoengineering, the best response for everyone else “to unilateral geoengineering might be a sharp increase in their own geoengineering effort.” A break-out, he says, could be stabilizing and make it easier to re-establish norms, because everyone’s “transparent endpoint is to re-assert collective control over the technology.” In Victor’s case, unilateral geoengineering may be no worse in the end than cooperation.

6. CONCLUSION

This paper examined three broad issues. First, it explored possible governance alternatives for geoengineering and characteristics a geoengineering regime should exhibit. Second, it asked how current events in geoengineering governance—the institutionalization of geoengineering moratoriums, which seems prudent today—could affect developments in the long term, potentially leaving the world unable to deal with dangerous climate change. Third, it asked how countries might react if a climate crisis occurred and no viable international geoengineering governance avenues existed. In a way, this essay presents a clear albeit hypothetical avenue for

how we might get from where we are today, with a piecemeal and parochial governance arena, to a situation where a country or group of countries act unilaterally. There is no determinism involved, however, only feedbacks and reflexivity.

The fundamental question this paper asks is how society can best handle the complexity, uncertainty and risk inherent in climate change. That is likely to be one of our biggest challenges in the future, though climate change is only one part of the wider issue of how we can become better stewards of the Earth. It is quite clear that existing governance mechanisms are inadequate. We must find better ways of governing environmental risk, with a particular focus on increasing the resilience of governance. Governance techniques like adaptive management, better communication between epistemic communities and the rest of society to ensure widespread understanding the inherent constraints of science, and increased integration of a wider array of stakeholders into the process of both governance and knowledge creation—as recommended by the post-normal science approach—can all increase the resilience of socio-ecological systems.

All due care must be given now in the discourse on geoengineering and climate change. If “a problem well defined is a problem half-solved,” we should pay close attention to how the geoengineering governance discourse is framed. What is the immediate problem? Clearly it is not intervention, but making sure that geoengineering research is exhaustive, and that if—and only if—some geoengineering schemes are deemed viable, we have them at our disposal. This paper is by no means pro-geoengineering—it is only interested in finding solutions to very concerning problems. More research is required in all areas of geoengineering, from basic science to socio-economic impacts. In light of the deleterious side-effects of stratospheric geoengineering, the challenge ahead is to steer geoengineering policy and the research agenda

onto a track that maintains the primary focus on mitigation, yet continues to explore geoengineering options.

The proper baseline of geoengineering, as far as stratospheric geoengineering is concerned, should be as a last resort or emergency option—that way, the question of using geoengineering techniques are not part of the normal policy debate, it is a contingency plan only. This may be a safer route to take than making the baseline of geoengineering a ban. As an added benefit, if potentially disruptive geoengineering is accepted as the end-point of failed mitigation, it might give countries the necessary incentive to commit to mitigation. Path-dependency theory supports Victor's (2008) concerns about the development of the field, indicating that we should not let anti-geoengineering sentiments take hold in a fragmented governance landscape. Unilateral geoengineering is no idle possibility, but it should not be the basis of geoengineering governance. To write off or condemn geoengineering on that basis is particularly ill-advised—rather, the scenario described in Section 5 should encourage us to redouble our mitigation and research efforts. Geoengineering may not be the only option or even the best option in the case of a climate emergency, but only rigorous research can determine how it can be implemented in the safest way possible, and only vibrant public debate can decide what risks and trade-offs are acceptable.

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