Clearing the Air on 'Geoengineering' and Intellectual Property Rights

Towards a framework approach

by

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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 final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

Abstract

A number of commentators have expressed concern about the role of intellectual property rights (IPRs) in climate engineering (CE) research and governance. However, these concerns have often been couched in general terms, and diverge in the relative importance that they attach to the issue. Whether, how, and why IPRs might matter for the governance of CE activities has yet to receive a comprehensive treatment; thus the policy and governance implications remain completely unclear.

To untangle the issue, this paper focuses on patents and trade secrets as the most relevant categories of intellectual property, and develops a framework within which to situate IP-related concerns, specifically as related to direct air capture, ocean iron fertilization, and stratospheric aerosol spraying. The paper shows that there is no *a priori* "yes or no" answer to the question of whether IPRs are desirable and appropriate for "geoengineering." Rather, the question of whether they ought to be encouraged or discouraged is highly conditional. We must first ask "What are the specific challenges that IP claims might pose for the technological domain in question?" Next, we must explicitly foreground normative concerns by asking, "Given the scale and distribution of potential risks and benefits, what is the *appropriateness* of introducing private property rights?" Only after we have answered these first two questions can we reasonably ask "What is the best way to incentivize research," and determine whether IPRs should be recommended or discouraged. The paper concludes by calling for an enhanced research program among CE and IP scholars on the relationships between IPRs and CE research, development, and governance.

Acknowledgements

In good form, I have left the most important piece of this puzzle for last: How to properly express my deep-felt gratitude to the countless individuals who have guided and supported me on this humbling journey of the mind and spirit? How to be both parsimonious and pithy in accounting for the most challenging and worthwhile chapter of my adult life? Even hierarchy in thanks strikes me as problematic – when struggling with a project over the long haul, small acts of support and solidarity can hold unanticipated weight and resonance. I cannot say that I am less grateful for these kindnesses than I am for the sustained and seemingly boundless faith placed in me by those more closely involved in my work. Perhaps it is best to abandon any illusion that perfection is achievable or desirable in the present task. I will have to trust, instead, that the very act of trying has its own inherent value.

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To those generations who may live to see realized our worst imagined fears

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Abbreviations

CCS – Carbon Capture and Storage

CDR – Carbon Dioxide Removal

CE – Climate Engineering

CO_2 – Carbon Dioxide

DAC – Direct Air Capture

ENMOD – UN Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques

GHG – Greenhouse Gas

HOC S&T - The UK House of Commons Science and Technology Select Committee

HSRC – Haida Salmon Restoration Corporation

IP – Intellectual Property

IR – International Relations

IPRs – Intellectual Property Rights

NGO – Non-Governmental Organization

OIF – Ocean Iron Fertilization

R&D – Research and Development

SAS – Stratospheric Aerosol Spraying

SPICE – Stratospheric Particle Injection for Climate Engineering

SRM – Solar Radiation Management

USPTO – US Patent and Trademark Office

1. Introduction

Controversies around Intellectual Property Rights (IPRs) have been embedded in what have arguably been the two most highly publicized climate engineering (CE) events – a planned SPICE[1] project field test in the UK (patent claims), and the rogue ocean iron fertilization (OIF) experiment conducted off the coast of Canada in 2012 by Russ George and the Haida Salmon Restoration Corporation (proprietary information). Unsurprisingly, a number of commentators have expressed concern about the role of Intellectual Property Rights in CE research and governance. However, these concerns have often been couched in general terms, and diverge in the relative importance that they attach to the issue. Whether, how, and why IPRs might matter for the governance of CE activities has yet to receive a comprehensive treatment; thus the policy and governance implications remain completely unclear. Should IP claims for CE be encouraged or discouraged? Why and according to what conditions? Given that R&D in CE is still at a relatively early stage, this discussion has been largely hypothetical, and has proceeded without an explicit framework within which to situate IP related concerns.

To untangle the issue, this paper focuses on patents and trade secrets as the most relevant categories of intellectual property.[2] I begin with the assumption that more research and knowledge diffusion on the science of climate engineering is in the public

[1] Stratospheric Particle Injection for Climate Engineering. See www.spice.ac.uk

[2] There are four core reasons for this focus: First, where IP has been raised as a concern for CE governance, reference is often made to patents. Second, SPICE and the Haida Salmon Restoration Corporation (HSRC) OIF experiment provide real-world examples of the relevance of these categories. Third, other forms of IPRs are almost certainly of less relevance, although it should be noted that copyright certainly imposes costs on the diffusion of research – particularly to less technologically connected and less wealthy research centres and individuals. That said, there are increasingly workarounds to publishing pay-walls, including the successful "Geoengineering Google Group." Finally, other forms of IP are scoped out of the current discussion simply due to length constraints.

interest.[3] With this core assumption, I attempt to develop a framework within which to situate and evaluate concerns, risks, and uncertainties around IPRs, with the aims of (1) helping researchers and policy makers to think more clearly about the issue, and (2) motivating a broader research agenda. This framework offers guidelines for determining the appropriateness and desirability of IPRs in CE. The inquiry proceeds by asking the following questions: (1) In what general ways might patents and trade secrets be important for CE research and governance? (2) In what ways might patents and trade secrets matter for particular CE interventions? (3) How should we[4] situate and evaluate the diverse views that have been expressed with regard to CE and IPRs?

The paper begins with a critical overview of climate engineering, covering the common technological distinctions (CDR & SRM), governance challenges (Ethical-Normative, Social/Technical Lock-In, and Over-Provision/International Security), and key governance principles (the Oxford Principles). While this may present familiar material for the established 'geo-clique,' I include it in the hopes of drawing broader communities – notably innovation scholars – into the conversation in an inclusive manner.

Building on this initial overview, I attempt to answer the first question by drawing on recent literature on the purpose and perils of patents and trade secrets. I describe the rationale for patents and IPRs, and the related tensions (embedded in the Oxford

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[3] The rationale for this assumption is as follows: robust decision making on CE depends on quality knowledge inputs. Absent research, stakeholders are unlikely to be able to sufficiently assess the risks and uncertainties associated with potential interventions. Moreover, much CE research – especially on SRM – may have spillover benefits for other areas of climate science. While some have argued that research invites a moral hazard, the opposite is at least as likely to be true: more research may demonstrate risks and consequences that reveal particular CE interventions to be completely undesirable. On this theme, see Caldeira, Ken, and Keith, David (2010), pp. 57-62.
[4] In this paper, "we" refers especially to researchers in the CE community, but more broadly to all those – including policy makers and the public – who are stakeholders in CE developments.

Principles) between the desire to incentivize innovation, to protect ‘private’ property, and to promote public goods. I show that while a well-designed IPR regime could theoretically facilitate positive social outcomes, trends over the past several decades have produced an IP landscape that often imposes costs and barriers to innovation, knowledge diffusion, and public good provision - in particular due to the expanded scope of patentable subject matter, and through the growth of patent trolls, litigation costs, vested interests, and rent-seeking behaviour. I argue that our analytical framework must thus ask “what is the most effective and efficient way to incentivize research and innovation, without imposing undue downsides and risks associated with a dysfunctional IP system?”

In addressing the second question, I suggest that whether and how IP matters is likely to vary depending on the proposed intervention in question, because the nature and acceptability of the risks associated with IP claims are likely to be very different across different CE techniques. To show this, I compare the risks and tradeoffs associated with direct air capture (DAC), ocean iron fertilization (OIF), and stratospheric aerosol spraying (SAS). While in general, IPRs might carry a more acceptable risk to benefit ratio for CDR interventions than for SRM, an effective analytical framework will ultimately need to evaluate the tradeoffs associated with IPRs and CE on a case-by-case basis.

In addressing the third question, I suggest that discomfort around IPRs is motivated only partly by the empirical concerns associated with a dysfunctional IP system and related public goods failures in areas like public health. In addition, there is a deeply normative dimension to the acceptability of IPRs. Drawing on Michael Sandel, I argue that we must engage directly with this normative question, which at its core

requires us to wrestle with the appropriateness of introducing market logics and market thinking to interventions that are as potentially transformative and culturally significant as some CE techniques may be. Only by explicitly foregrounding such concerns can we hope to determine whether and under what conditions IPRs ought to be encouraged.

In the final section, I summarize the evaluative framework, which operates in a tiered fashion. I show that there is no *a priori* "yes or no" answer to the question of whether IPRs are desirable and appropriate for "geoengineering." Rather, the question of whether they ought to be encouraged or discouraged is highly conditional. We must first ask "What are the specific challenges that IP claims might pose for the technological domain in question?" Given that the label "geoengineering" in fact lumps together a number of highly disparate proposals, the answer will be very different depending on the intervention being discussed, and the associated "geoengineering governance challenges" that are involved. Next, we must explicitly foreground the normative dimension by asking, "Given the scale and distribution of potential risks and benefits, what is the *appropriateness* of introducing private property rights?" Only after we have answered these first two questions can we reasonably ask "What is the best way to incentivize research" and determine whether IPRs should be recommended or discouraged. Returning to the examples of DAC, OIF, and SAS, I argue that IPRs are likely advisable in the first case, of ambiguous value and appropriateness in the second, and wholly inappropriate in the third.

I conclude by calling for an enhanced research program among CE and IP scholars on the relationships between IPRs and CE research, development, and governance. I suggest that ongoing monitoring – in particular of the patent landscape and

its effects on the field -- will be essential to effectively governing CE in a flexible and adaptive manner.

2. A critical overview of climate engineering

2.1 Categories of CE

Climate engineering goes by a diverse and growing number of names,[5] hinting at the challenges involved in specifying exactly what does or would constitute such an intervention. One oft-cited definition (of 'geoengineering') was provided by the UK Royal Society in 2009: "the deliberate, large-scale manipulation of the planetary environment to counteract anthropogenic climate change."[6] Intent and scale are the key definitional variables here, but they both complicate governance discussions, and the latter remains particularly underspecified.[7]

While a seemingly all-encompassing term like "geoengineering" may serve to capture the imagination, it is not particularly helpful for actually thinking about the types of activities it ostensibly describes. "Geoengineering" involves such a wide variety of potential techniques and technologies to intervene in the climate system and/or sequester carbon dioxide that they cannot be accurately subsumed by one catchy title.

There are at least two major categories of potential interventions into the climate system typically referenced in discussions on CE – Carbon Dioxide Removal (CDR) and Solar Radiation Management (SRM) – each with significant differences that can be obscured by the totalizing nature of a term like "geoengineering." While "climate

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[5] E.g. geoengineering, terraforming, climate remediation, planet hacking, etc.
[6] Shepherd et al. (2009).
[7] If only large-scale (ie. planetary) activities count as geoengineering, for example, then presumably all smaller-scale research that would be needed to get to full-scale deployment would not be regulated as 'geoengineering' per se. Furthermore, some so-called 'geoengineering' schemes might involve interventions that are not obviously 'global' – as in the case of proposals to intervene regionally in the Arctic to prevent ice melt. Clearly there must be some governance of smaller-scale activities, however it's not immediately clear – based solely on definitional criteria of scale and intent - why a tiny and localized aerosol spraying experiment might be subject to scrutiny and even outrage while a neighbourhood roof-whitening initiative, or a national afforestation program might not.

engineering" isn't obviously superior, it is an effort to at least begin to move away from "geoengineering" as a totalizing concept. Wherever possible, I will avoid CE or 'geoengineering,' and simply refer to CDR or SRM directly.[8]

CDR techniques such as the Haida Salmon Restoration Corporation (HSRC)'s OIF experiment would reduce global warming by actively drawing down carbon dioxide from the atmosphere and sinking it in another part of the earth's systems.[9] Other proposals include spreading lime or crushed limestone to reduce oceanic acidity, large-scale tree-planting, biochar, and direct-air capture (DAC).[10] The ambiguities of scale, intent, effectiveness, and risk associated with these diverse proposals further underscore the challenge of lumping them together under a common moniker.

To deploy at a scale large enough to have a substantial impact on the global climate, CDR techniques could involve significant regulatory, financial, and infrastructural commitments, in particular for pumping, transporting, storing, and monitoring sequestered gases. In his 2013 book *Earthmasters*, Clive Hamilton keenly observes that:

"The essential difficulty with all carbon dioxide removal approaches is that they want to

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[8] These terms may also be too all encompassing. CDR in particular currently describes activities that are very diverse in their potential impacts and regulatory challenges. For example, it is unclear whether it is particularly fruitful to discuss carbon capture and storage and direct air capture under the same conceptual framework as ocean iron fertilization and enhanced geological weathering. SRM could be described as almost laughably technocratic; however 'managing' solar radiation – to whatever degree we can - may indeed be where we need to go.

[9] Direct air capture, while facing the same storage, pumping, and monitoring challenges, is nonetheless distinct from carbon capture and storage (CCS), which seeks to scrub carbon emissions at their point of production, for example from coal powered electricity plants. Whether direct air capture (or indeed most CDR techniques) should be described as 'geoengineering' or 'climate engineering' at all is an open question; however there is no credible case for describing CCS as such. It is unambiguously a mitigation technique, aimed at reducing emissions at source.

[10] This non-exhaustive list is adapted from Hamilton (2013), pp. 20-50.

push a reluctant genie back into the bottle. It took the Earth millions of years to immobilize a large portion of the planet's carbon in fossilized form deep underground. When we extract and burn it we mobilize the carbon and there is no place on Earth where, over human timescales, we can safely sequester it again… Even if such a place could be found there is something deeply perverse in the demand that we construct an immense industrial infrastructure in order to deal with the carbon emissions from another immense industrial infrastructure, when we could just stop burning fossil fuels."[11]

SRM techniques would intervene quite differently and with more immediate effect in the climate system. Rather than removing carbon dioxide (or perhaps other greenhouse gases)[12] from the atmosphere, SRM schemes would limit the amount of

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[11] Hamilton (2013) pp. 49-50. This observation certainly applies to direct air capture (DAC), and to carbon capture and storage (CCS). Other techniques, such as OIF or limestone spreading would similarly require large-scale and continuous effort to make so much as a dent in ongoing emissions and ocean acidification. Hamilton's comments hint not only at the technical challenges associated with CDR, but also at the normative concerns that motivate much discomfort with the idea of climate engineering. The common protest '*Why not simply address the challenge directly, and cut emissions?*' is bolstered by the moral sense that to do otherwise is to fundamentally avoid responsibility for a problem of our own creation. Yet the seemingly inextricable links between energy production and economic growth, and between economic growth and political liberalism and stability should underscore the immense challenges of quickly and dramatically changing our global emissions trajectory. Moreover, while the West might conceivably cut emissions, if not energy consumption, both consumption and emissions must almost certainly rise throughout the developing world to provide an adequate standard of living to the wide swath of humanity that currently lacks one. Finally, carbon dioxide is a long-lived greenhouse gas. Given its persistence in the atmosphere and the possibility of positive feedbacks and non-linear warming events, even if we *could* find a way to halt or sequester all emissions today, we would still face an atmosphere dangerously overloaded with carbon dioxide for centuries to come. These challenges may ultimately make SRM deployment both more desirable and more likely, whether as an alternative or as a complement to CDR, and regardless of mitigation policies.

[12] A critical reader might wonder why this paper focuses on carbon dioxide and largely ignores other greenhouse gases. I will offer three principle reasons. First, this is simply an issue of scope and length. Second, it is an issue of consistency: CDR is a widely-used and well-accepted category in CE discussions; no such category yet exists for methane or nitrous oxide, for example. Finally, it is an issue of conceptual relevance: SRM technologies would act on the cumulative effect of all greenhouse gases – an extended discussion about the relative role of different gases in anthropogenic warming is

incoming solar radiation entering the earth's systems in the first place.[13] Among the most plausible and actively researched proposals are marine cloud brightening and stratospheric aerosol spraying – the latter being the subject of the SPICE project's research.[14] Unlike CDR, SRM would not seem to require exceptionally large infrastructural or financial commitments – a relatively small-scale intervention could have global effects. Furthermore, while CDR – particularly in the form of direct air capture – would require ongoing, distributed action across a large geographic scale by a large number of potential actors in order to have a measureable impact, SRM could be deployed by one country with the willingness to set a small fleet of planes to the task.[15]

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irrelevant here. Different gases clearly have different sources, emissions profiles, properties, and effects, however this seems to matter little for Solar Radiation Management, except insofar as (e.g.) a hypothetical large methane release from permafrost or sea-bed deposits might induce rapid-onset warming and help mobilize support for SRM. As for gas removal and sequestration, there have been some limited discussions on gases other than carbon dioxide. However, these ideas remain largely hypothetical, while Co2 removal remains by far the most actively researched and discussed. Moreover, should techniques to remove other gases be developed and deployed, I see no reason why the conclusions of the present discussion on IPRs would be substantially different than for CDR techniques. For all these reasons, it seems unnecessary to dissemble further on other GHGs in this paper. Thanks to Simon Dalby for highlighting this gap.

[13] CDR and SRM are commonly accepted categories, but I do not wish to claim that they are sufficiently representative of all the activities that may ultimately be relevant to discussions around CE. A third category "Thermal Radiation Management" – attempting to increase the amount of heat energy radiating from the earth out into space may prove to be a worthy addition to the lexicon. See Hamilton (2013). For now, we might simply think of "other large-scale manipulations." See American Meteorological Society (2013) and Long and Winickoff (2010).

[14] Critically, SRM interventions could conceivably slow the *rate* of warming caused by a given atmospheric concentration of greenhouse gases, which could lesson the impact of a given amount of warming on socio-ecological systems, by spreading it out over a longer time-horizon. SRM could also buy time to stabilize atmospheric concentrations of GHGs at a safer level, and smooth the transition to net-zero-emission social, economic, political, and cultural systems that such stabilization (if possible) will require.

[15] While it is tempting to imagine military deployment of such techniques, weather and climate modification got a bad name during the Cold War, particularly following revelations that the United States had undertaken a multi-year campaign of clandestine cloud seeding as a form of environmental warfare in Indochina. The United Nations Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (hereafter ENMOD) was later drafted to prohibit future attempts to control weather or the climate for military purposes. On this history, see Fleming (2010), especially pp. 179-187

2.2. Governing climate engineering

Given the complex risks and challenges broadly associated with different approaches to CE, it is troubling that so little governance seems to exist. While a growing number of articles, reports, and conferences have attempted to wrestle the issue into a tractable form, there remains little to no international or domestic legal guidance to address CE research, testing, or deployment.[16]

The Oxford Principles for Geoengineering Research, proposed in 2009 by a multidisciplinary group of researchers, are the best guide we have to help us think about governance, and will help to ground our inquiry into IPRs. The UK House of Commons Science and Technology (HOC S&T) Select Committee and the UK Government endorsed the Principles, thereby offering "the only official national-level policy statement on geoengineering in the world to date."[17]

The Principles were intended to provoke discussion and "provide a flexible architecture, operating at different levels, and involving formal and informal mechanisms depending on the stages of research and the issues raised by a particular technology."[18] While the Principles have been criticized for lacking much in the way of specifics, they

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[16] In a 2011 report on behalf of the German Federal Ministry of Education and Research, the Kiel Earth Institute evaluated the potential applicability of existing international laws to CE activities. While some such activities might be minimally covered under current framework approaches, the report concluded that the legality of specific technologies must ultimately be assessed on an individual basis. In general, existing international laws provide ambiguous, limited, and partial coverage at best. No binding or consensus definition of 'geoengineering' exists, nor are there specific national or international rules or laws to guide research, testing, and deployment, nor to govern related disputes. While national governments perhaps recognize the need for greater governance, they have stopped short of banning or intervening in climate engineering activities. Indeed, their role appears to be one of supporting further research, rather than standing in its way. See Rickels et al. (2011), especially pp. 85-105.

[17] Oxford Geoengineering Program (2015) "The Oxford Principles: History."

[18] Rayner et al. (2013).

were in fact designed to be both "high-level and abstract." As Rayner et al note, "Given the heterogeneity of proposed geoengineering methods and their varying degrees of development, it is undesirable, if not impossible, for the Oxford Principles to be anything but high-level. A 'one-size fits all' approach is certainly not appropriate."[19] Nonetheless, by providing a framework against which CE activities might be developed and judged, they "suggest how those engaged with geoengineering might be called to account." Moreover, each of the Principles "was intended to capture a widely held societal value that should be respected in the development of all geoengineering technologies."[20]

The first Principle proposes that CE be "regulated as a public good," however the authors clarified to the HOC S&T Committee that "private sector involvement should be encouraged, albeit with a regulatory framework that would help to stymie the creation of vested interests," notably with regard to IPRs.[21] This Principle derives from the recognition that "all of humanity has a common interest in the good of a stable climate... and therefore the means by which this is achieved."[22]

Principle 2 advocates for "public participation in geoengineering decision-making," and "suggests a primary concern for legitimacy."[23] Tim Kruger notes that there are both normative and substantive reasons for public participation, however he and the other authors reject a one-size fits all approach to what such participation might look like.[24]

The third Principle "requires the prompt and complete disclosure of research plans and open publication of results," including those from computer modeling. The Principle

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[19] Ibid.
[20] Ibid.
[21] Kruger (2013).
[22] Rayner et al. (2013).
[23] Ibid.
[24] Kruger (2013).

appeals to the "procedural value of transparency" and aims to promote "better understanding of the risks," and protect public trust.[25]

Principle 4 calls for "independent assessment of impacts," building on the previous two Principles' recognition of transparency as a "necessary – though not sufficient – requirement to obtain the 'social license to operate'" and one that has both normative and substantive value.[26]

Finally, the fifth Principle calls for "governance before deployment…using existing rules and institutions wherever possible,"[27] but recognizing that some transboundary activities may require new or reformed agreements and institutions. [28]

Principles 2 through 4, emphasizing legitimacy, transparency, and public trust, suggest the central importance of social license for the Principles' authors. Moreover, there is an unresolved tension between this concern for social license and the desire to promote private involvement in R&D (per Principle 1). This tension was evident in the case of the SPICE patent claim, which led to the perception of a conflict of interest between public aims and private gain. It was perhaps even more obvious in the case of the HSRC's 'rogue' OIF experiment: Absent public participation, research transparency, or an independent assessment of impacts, the experiment lacked the key ingredients required to be perceived to be serving the public good. Without the required social license, the event was subject to international condemnation.

The issues that the Principles would help us to confront "are as varied as the technologies under consideration." Nonetheless Rayner et al. highlight a number of

[25] Rayner et al. (2013), Kruger (2013).
[26] Kruger (2013).
[27] Kruger (2013).
[28] Rayner et al. (2013).

specific, interrelated governance challenges, allowing us to develop a rough typology.[29] It must be emphasized, however, that given heterogeneity of CE techniques, not all proposed interventions will be subject to the same type or severity of governance challenges.

The first group of challenges involves the ethical and normative dimensions associated with deliberately intervening – at large scale – in the climate system. Here, governance must address whether or not climate engineering activities *should* take place, on what basis such decisions should be made, and through what mechanisms. The ethical and normative dimensions of climate engineering demand that we seek to balance social justice, legitimacy, and accountability with expediency, effectiveness, efficiency, and cost. These questions are directly related to the uneven distribution of power and influence within the global political economy, the asymmetrical distribution of climate change responsibility and impacts, and the likelihood that any action will generate uneven costs and benefits across different countries, regions, and generations.[30]

Complicated questions of identity and culture are important here as well. 'Geoengineering' can provoke an "underlying feeling of abhorrence,"[31] perhaps in part because it involves a profound and explicit reframing of our species' relationship with the planet – a point of no return beyond which any illusion that the 'social' and the 'natural' are separate is impossible to maintain. Indeed, David Keith has suggested that "deliberate planetary engineering would open a new chapter in humanity's relationship with the earth."[32] On the other hand, the idea of climate engineering also pulls at deeper, well-

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29 Rayner et. al. (2013).
30 MacMartin et al. (2013).
31 Ibid.
32 Keith, David (2010a), p. 495.

established tropes of forbidden knowledge and over-reaching hubris, or of progress and triumphalist domination over 'natural' limits and obstacles. Given the scale, impact, and potential cultural gravity of some CE activities, it is unsurprising that normative concerns also include a debate over the appropriate role of the private sector in research and deployment.[33] As we shall see further on, normative discomfort with the role of markets and private actors in global governance generally is a key dimension of concerns around the role of IPRs in CE.

The second, related group of challenges concerns the risk of path dependence and different forms of technical and social-lock in.[34] Should SRM be deployed without reducing emissions, for example, human societies would become vulnerable to intermittency and the "termination effect,"[35] wherein the cessation of deployment results in a "rapid rise in global temperature that could be harder to manage than any temperature increase that would have occurred without intervention."[36] Any number of scenarios could plausibly precipitate such an effect, including the emergence of unacceptable risks or unintended consequences, or the arrival of additional catastrophes, such as warfare, economic collapse, or a global pandemic.[37] Should normative opposition to intervention become fanatic, ideologues could work inside or outside the political system to shut down activities without scientific due-diligence. It should also be noted that the mere (unsubstantiated) perception of ill effects – such as extreme weather events, crop failures, or disease outbreaks – could be enough to mobilize support for a cessation or contestation of SRM deployment.

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[33] Rayner et al. (2013).
[34] For a useful discussion of path dependence, see Pierson (2004).
[35] Shepherd et al. (2009), p. 35.
[36] Rayner et al. (2013), p. 4.
[37] See for example Baum, Seth D., Maher, Timothy M. Jr., and Haqq-Misra, Jacob (2013).

Social lock-in is also a concern. It has been suggested that patent ownership and capital-intensive techniques with high sunk costs could create vested interests and lead to regulatory capture. Without effective governance to preclude such capture, research could create undesirable incentives for deployment, and deployment could be maintained for non-scientific reasons.[38] If vested interests are established, it could be difficult to cease CE operations once they have begun. Path dependence also raises an explicitly normative question that governance must somehow address: is it appropriate for future generations to be saddled with the multiple risks and responsibilities of maintaining interventions into the climate system over the long term?

A third group of challenges is related in part to the relatively low technical and financial barriers to deployment of some techniques – especially SRM – and more generally to the geopolitical implications of deliberate interventions into an already unstable climate. Here scholars have pointed out that, in contrast to the free-rider problem of GHG reduction efforts, some climate engineering actually involves a *free-driver* problem. The incentives involved make it difficult to prevent unilateral action on the part of wealthy individuals, individual states, or small coalitions.[39] The potential for unevenly distributed impacts, unintended consequences, and the challenge of definitively attributing specific local or regional climatic phenomena to climate engineering – when combined with the relatively low costs of techniques like stratospheric aerosol spraying – all raise the potential for distrust and international conflict over deployment.[40]

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[38] Rayner et al. (2013), p. 5.
[39] Barrett, Scott (2007).
[40] See also Weitzman, Martin L. (2012), Urpelainen, Johannes (2012), Gardiner, Stephen M. (2013), and Macnaughten and Szerszynski (2013).

3. Climate engineering and IPRs: General considerations

Having reviewed the basic categories of climate engineering (CDR & SRM), the most concrete guide for governance of CE (the Oxford Principles), and the governance challenges commonly associated with engineering the climate, we can begin to turn our attention more directly to IPRs. Two recent events have helped to elevate Intellectual Property Rights as an area of potential relevance and concern.

First, a UK research project, having already provoked discomfort among some environmentalists and the public, descended into further controversy when it was revealed that two people close to the project had filed a patent claim. The Stratospheric Particle Injection for Climate Engineering (SPICE) project planned a field test in which water would have been pumped a kilometer above ground through a hose to a balloon, and dispersed into the air. The aim of the test was to collect data that "would be used to validate computer models" and "inform the design of a 20km tethered balloon for delivering reflective aerosols to the stratosphere."[41] The test was cancelled however, due to concerns about governance, and a perceived conflict of interest around IP. Specifically, two people close to the project had filed a patent application for the balloon technology before the SPICE project was proposed, but had failed to disclose this widely to the rest of the team. In addition to worries about a general lack of CE governance, the revelation around the patent filing caused "significant discomfort" among team members.[42]

Then in 2012, an American entrepreneur carried out a rogue ocean iron fertilization (OIF) experiment in Canadian waters, absent not only provincial and federal

[41] Kuo, Kirsty (2012, June 18).
[42] Cressey, Daniel (2012, May 15).

permission and oversight, but also lacking much in the way of proactive disclosure of his plans, methods, or data. Russ George, funded by the Haida Salmon Restoration Corporation (HSRC), spread some 100 tons of iron dust over the ocean on the West Coast of Canada. The goal was ostensibly to revitalize local salmon populations, but George and the HSRC also hoped to sequester carbon dioxide (CO_2) and thereby cash in on carbon credits. Following international condemnation, Environment Canada has launched an investigation and George has been fired by the HSRC. While the HSRC has pledged to make its data freely available through open-access, George took possession of a number of "computers, assets and samples" and filed an application with British Columbia's Supreme Court to stop the company from sidelining him, calling "the actions of the board 'oppressive and unduly prejudicial' to his rights and interests."[43] It remains to be seen whether the experiment was successful in its goals, however evaluating the full ecological and climatic effects of this and any future experiments will likely prove impossible absent transparent access to and accountable oversight of plans, methods, and data.

Claims about IPRs and CE fall on a spectrum, but most commentators have expressed some concern. David Keith, a prominent researcher in the SRM community and an entrepreneur in CDR, has repeatedly argued against SRM patents, suggesting that "for these solar radiation technologies, it's dangerous to have it be privatized… The core technologies need to be public domain." On the other hand (and in the same article), Keith suggests that "Patents are mostly symbolic in this area anyways."[44] More substantively, in response to questions about the role of the private sector in

[43] Hume, Mark (Jan 6, 2014).
[44] Mulkern, Anne C., and ClimateWire (Apr. 18, 2012).

'geoengineering,' a memorandum submitted to the UK House of Commons Science and Technology Committee sought to "draw attention to the particular issue of patents and other intellectual property rights in this area," and warned that allowing patents "could have serious negative impacts," including the creation of "a culture of secrecy" and "the concealment of negative results;" "the creation of powerful vested interests" and "undesirable technological lock-in;" and "delays and needless expense" due to rent-seeking."[45] Similarly, Jane Long of the Lawrence Livermore National Laboratory has warned that "We will need to protect ourselves from vested interests [and] be sure that choices are not influenced by parties who might make significant amounts of money through a choice to modify [the] climate, especially using proprietary intellectual property."[46] Some claims go even further. Clive Hamilton has ominously warned that "we are approaching a situation in which international efforts to protect humanity from climate catastrophe could depend on whether or not one company wants to sell its intellectual property."[47] In 2010, Parthasarathy et al. made perhaps the boldest claim, arguing that with current trends, we risk allowing patents to become "the *de facto* form of governance" of geoengineering activities.[48]

To begin to make sense of and evaluate these concerns, we must ask our first question[49]: In what general ways might patents and trade secrets be important for CE research and governance? To answer, it will be useful to first return to the rationale for patents and trade secrets, and the gulf between what they are supposed to promote, and

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45 Kruger et al. (2010).
46 Qtd. in Vidal, John (2012). See also Long, Jane C. S., and Scott, Dane (2013).
47 Hamilton (2013), p. 80.
48 Parsatharathy et al. (2010).
49 For the present analysis, it helps to ask this first, so as to lay out some general considerations about IPRs. When it comes to the framework approach, however, this will actually be the final consideration.

how the contemporary IPR regime often operates.

Patents are government-granted monopolies, bestowing the right "to exclude others from making, using, offering for sale, or selling … or importing the invention." This right is granted "in exchange for public disclosure of the invention when the patent is granted."[50] According to Primi, these monopolies are granted in order to fulfill twin functions of "appropriability" and disclosure: since information is non-rival, intellectual property rights are required to provide a means of appropriation, and in order to provide incentives for research and innovation that would otherwise be subject to free-riding. Innovation ultimately improves social and economic welfare (for example by generating new knowledge and goods), however, according to patents' supporters, granting a time-bound monopoly is required to encourage it. The disclosure of the invention is required in order to ensure that knowledge is diffused rather than hidden, that the invention can be replicated, and that the full benefits of the innovation eventually enter the public domain. Disclosure is also "generally assumed to increase efficiency" and "prevent the duplication of R&D efforts." In short, IPRs "aim at balancing the interests of those who innovate and those who would benefit from innovation."[51]

Patents can – in theory – provide a balanced approach to incentivizing research, innovation, knowledge diffusion, and creative destruction. As Burlamaqui argues, "if carefully used, intellectual property rules *can be* sources of dynamic efficiencies that can help to *ignite* the Schumpterian positive-sum game represented by falling costs, falling prices, positive margins… and increased consumer [and social] welfare." However, in practice, the current global IPR regime often functions very far from this ideal.

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[50] US Patent and Trademark Office http://www.uspto.gov/patents/index.jsp
[51] Primi, Annalisa, (2012).

It is easy to take the current IP landscape for granted, but to do so would neglect how much things have changed – particularly over the past four decades. Burlamaqui argues that "Until the 1970s, patents were seen as monopolies (a term with distinctly negative connotations at that time), not rights." Since then, "the boundaries of the private (or corporate) interests has [sic] been hyperexpanded while the public domain has significantly contracted." As IPRs have been construed and understood increasingly as inherent private rights rather than limited public-interest serving privileges, protection has expanded in scope, duration, and geographical scale through international trade negotiations and US-led efforts towards standardization.[52]

From the comparatively humble beginnings of the patent system, the scope of patentable subject matter has expanded enormously, such that patents have become "easier to get, [and it has become] easier to enforce patents against others, easier to get large financial awards from such enforcement, [and] harder for those accused of infringing patents to challenge the patents' validity."[53]

Moreover, in the US at least, the legal costs associated with patents have skyrocketed, such that "a regime that had been committed to fostering and protecting innovation" has been transformed "into a lawyers' paradise."[54] This transition has coincided with the growth of so-called patent trolls (also known as non-practicing entities or patent-assertion entities) – "companies set up for no other purposes than buying and exploiting the inventions of others" often "with the intent of suing first and asking questions later."[55] A related phenomenon is "strategic patenting," described by

[52] Burlamaqui, Leonardo (2012).
[53] Cited in Burlamaqui (2012), p. 21.
[54] Burlamaqui (2012), p. 21.
[55] Fisman, Ray (2012, Apr. 9).

Burlamaqui as "the proliferating business strategy of applying for patents that the company has no intention of using, or exploiting, solely to prevent others from profiting from the innovation."[56] Moreover, so-called trolls are also known "to lay low and then take a mature industry by surprise once participants in the industry have made irreversible investments."[57] Unsurprisingly, patents are increasingly being filed and collected for defensive use as well – most famously in software and communications technology sectors.[58]

The sum result is an IP system that, while undoubtedly beneficial to some actors and perhaps crucial to some industries, is nonetheless plagued by "dynamic inefficiencies" "unproductive entrepreneurship" and "information feudalism" – a system that imposes significant social costs, and "that is likely to stifle innovation at the same time as it concentrates wealth."[59]

Unsurprisingly, these trends have been associated with significant public goods failures in domains such as global public health. The concerns of commentators including Kruger et al. and Parsatharathy et al. seem to reflect these experiences.

Patents have famously been implicated in reinforcing global divides in access to medicines. Muzaka notes, for example, that "against the backdrop of growing concern over global public health challenges, and particularly over the escalation of the HIV/AIDS crisis … strong private IPRs were framed as an obstacle to the enjoyment of human health and life." Using language such as "medical apartheid" and "patent

[56] Burlamaqui (2012), p. 9. See also Primi (2012), pp. 38-40 for an extended discussion on patents as strategic assets.
[57] Lemley, Mark A. (2008).
[58] See e.e. Duhigg, Charles, and Lohr, Steve (Oct 7, 2012).
[59] Burlamaqui (2012), p. 19.

versus patients,"[60] the Access to Medicines NGO network "linked strong IP protection for pharmaceuticals and high prices for prescription drugs … with restricted access to medicines and unnecessary loss of human health and life."[61] Furthermore, patents have artificially inflated the price for diagnostic procedures, prevented the development of better tests, "prevented patients from obtaining second opinions and confirmatory tests,"[62] and even prevented the communication to patients of diagnostic information that is discovered by accident. Unsurprisingly, such patents have been the subjects of a growing number of lawsuits.[63]

Trade secrets deserve some scrutiny here as well. Unlike patents, trade secrets do not need to be new or original to merit protection. Instead, a trade secret (also referred to as proprietary information) can be "virtually anything that is secret, and that imparts value to its holder as a consequence of that very secrecy," so long as the holder takes reasonable steps to keep it secret. Thus "technical and scientific information, such as formulae, manufacturing methods and specifications, designs, computer code and the like" as well as "commercial and financial information" are all commonly held as trade secrets. So too is "so-called 'negative' information" such as unfavorable test results, "the details of failed efforts to remedy problems in the formulation or manufacture of certain products, dead-ends encountered in research, [and] abandoned technical solutions."[64]

Trade secrets are "arguably the most important and most litigated form of intellectual property," but have been referred to as "parasitic;" trade secret law has also

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60 Muzaka, Valbona (2011), p. 130
61 Muzaka (2011), p. 76
62 Stiglitz, Joseph (July 14, 2013).
63 Picard, André (Nov 3, 2014).
64 Duston, Thomas, and Ross, Thomas (2013).

been accused of being "in a state of disarray."[65] There has been much debate around whether trade secrets should be considered property at all, and whether trade secret protection is justified. While economic, philosophical, and populist justifications have all been put forward, "none of these include an incentive to innovate as a primary feature."[66] Instead trade secrets are said to be justified primarily "by the economic benefits that flow from their existence, most notably incentives for business to spend less money protecting secret information or attempting to appropriate secret information;" under a "Lockean 'labor value' theory;" and "as a means for the public to enforce populist norms about 'commercial ethics.'"[67] Without protection from "misappropriation," in other words, companies would risk losing the value and advantage conferred by the information they have developed or acquired, would have to devote more resources to its protection, and would be more inclined towards unethical behaviour to appropriate information from other firms.[68]

Like patents, trade secrets have been the subject of controversy, and sites of contestation between public and private interests. In healthcare, trade secret protection has allowed misleading information to be communicated to healthcare professionals and patients, and has even been used to conceal drug trial deaths. Further, trade secret protection in research data – including data generated through regulatory and approval processes – has impeded innovation, risked public health, and imposed broad social costs.[69]

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65 Cited in Risch, Michael (2007), pp. 3-4.
66 Risch (2007), p. 4
67 Risch (2007), pp. 5-6
68 See Risch (2007) for an extended and worthwhile review and discussion of the possible justifications for trade secret protections.
69 See Ünlü, Mustafa (2010). See also Brezis, M. (2008).

Despite these issues, many firms continue to view trade secrets as highly valuable and as critical for innovation, and even for collaboration, through licensing and non-disclosure agreements. Trade secrets and patents are understood to be complementary, since patentable subject matter is often treated as a trade secret before patent filing, and since "trade secret laws apply to areas that patent law cannot" and are "particularly useful in protecting tacit or non-codifiable knowledge, namely information required for the implementation of a patented invention." Trade secrets also allow theoretically indefinite protection and preservation of advantage, and can provide a more immediate and "resource-effective" avenue to protect an innovation than patents.[70] Indeed, as the International Chamber of Commerce suggests, trade secrets "are often the 'crown jewels' of a firm's intellectual capital," comprising as much as "70 per cent of the value of the companies' intellectual assets," and understood to be a "key source of competitive advantage."[71] In contrast to the above concerns that trade secrets can impede knowledge diffusion – especially to public stakeholders – the International Chamber of Commerce points to their importance as a vehicle for knowledge diffusion and collaboration among firms, "by creating a safe environment for firms to share information that, for whatever reason, they haven't patented."[72]

This ambiguity surrounding the utility, effectiveness, and social value of trade secrets is echoed in the literature on patents. Despite their problems, many firms and industries hold up patents as critical to innovation. Nonetheless, empirical studies have cast major doubt on their broad effectiveness. Boldrin and Levine argue that "there is no empirical evidence that they serve to increase innovation and productivity… in spite of

[70] Brant, Jennifer, and Lohse, Sebastian (2014), pp 9-10
[71] Brant, Jennifer, and Lohse, Sebastian (2014), p. 11
[72] Brant, Jennifer, and Lohse, Sebastian (2014), p. 11

the enormous increase in the number of patents and in the strength of their legal protection we have neither seen a dramatic acceleration in the rate of technological progress nor a major increase in the levels of R&D expenditure."[73] The patent system in its current form, they argue, functions largely to preserve the market position of the largest, most established, and least inventive firms, at the expense of new market entrants, competition, and innovation.[74] On the other hand, other studies have suggested that "the stakeholders in IPR systems and their interests depend both on sector and on firm size."[75] Even if the aggregate empirical case for patents is poor, it appears that while patents can be dysfunctional or irrelevant for some firms and sectors, they might be highly important for others.[76]

Where does all this leave us with regard to CE? Returning to the core assumption of this paper, as stated at the outset, more research and knowledge diffusion on climate engineering proposals is taken to be an unqualified good at this stage. The above discussion suggests that – at best – there is an ambiguous relationship between patents and trade secrets on the one hand, and innovation and knowledge diffusion on the other. Patents, then, *could* serve to incentivize R&D spending in CE by safeguarding against free-riding and providing a profit-making mechanism, and could serve to facilitate knowledge diffusion through mandatory publication and licensing. However, in light of the experiences of health care, biotech, and pharmaceutical researchers and professionals (not to mention the broader public), commentators are right to worry that patents and trade secrets could also restrict knowledge flows and basic research by imposing costs

[73] Boldrin and Levine (2012), p. 1. See also Torrance, Andrew W., and Tomlinson, Bill (2009).
[74] Boldrin and Levine (2012), p. 20.
[75] Anderson, Birgitte (2006), p. 7.
[76] See also Davis, Lee, N. (2006) pp. 148-176.

and barriers to research, experiments, and research tools (e.g. models, tests, or components). Moreover, while patent publication is supposed to serve the function of information diffusion and promote further innovation and "inventing around" the patent, in practice broad patent language often precludes inventing around, and "it is quite common that the information disclosed in patents is inadequate or opaque."[77] Early strategic patenting could place further constraints on research and knowledge diffusion, especially should so-called patent trolls enter the CE space solely to extract rents, without playing an active role in research or development themselves. By either encouraging or impeding knowledge diffusion, collaboration, and innovation, patents and trade secrets could significantly influence the speed and scope of CE development; have a major impact on technological development pathways and the structure of any CE industry; and determine the effectiveness and legitimacy of any governance regime.

Vested interests & rent-seeking are another problematic possibility, as highlighted by Kruger et al, Long, and others. As the above discussion has revealed, in domains such as the pharmaceutical and biotech sectors, patents and trade secrets have promoted rent-seeking behaviour by both practicing and non-practicing entities (patent trolls), and the creation of vested interests has allowed for regulatory, science-communication, research, and access-to-medicine outcomes that have worked against the public interest.

To the extent that patents promote knowledge diffusion and transparency (i.e. through publication and licensing), they could aid in the Oxford Principle goals of public participation, disclosure and publication, and independent assessment of impacts. Conversely, should CE patents have the opposite effect and impede knowledge diffusion, they could work against the achievement of the Principles' goals. Similarly, trade secrets

[77] Primi (2012), p. 37.

could have a positive impact should they encourage collaboration and knowledge diffusion among R&D actors. However, it seems likely that they might also put up barriers to meaningful public participation in decision-making and the independent assessment of risks and impacts, as has been observed in other domains.[78] Moreover, trade secrets run completely counter to Principle 3, which "requires the prompt and complete disclosure of research plans and open publication of results."[79] Finally, and relatedly, patents and trade secrets could play a large role in shaping public perceptions and trust, social license, and the perceived (as well as actual) legitimacy and effectiveness of decision-making, approval, regulatory, and monitoring processes.[80] Such impacts might play out in surprising ways. For example, the SPICE patent claims produced a controversy that effectively shut down the research stream in question, thus impeding whatever knowledge flows and basic research production would have resulted from the conclusion of the project. Another interesting example is the so-called "Chemtrails" conspiracy. Its subscribers are among the most actively interested in and vocally opposed to "geoengineering;" patents appear to have been a subject of some fixation and a key piece of alleged evidence in support of their worldviews.[81]

All things being equal, the primary determinant of whether IPRs in CE should be encouraged or resisted would be whether or not they facilitate or impede R&D, knowledge diffusion, and optimum technology diffusion, particularly in the context of the

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78 Norton Rose Fulbright (2013).
79 Rayner et al. (2013), Kruger (2013)
80 See Norton Rose Fulbright (2013) for a discussion of trade secrets & regulation.
81 See e.g. Geoengineering Watch (Aug. 8, 2012): "For anyone doubting the existence of the phenomenon of 'chemtrails', please take a minute to read through this extensive list of patents from America on equipment and processes used in just such programs. The evidence is clear folks." http://www.geoengineeringwatch.org/an-extensive-list-of-patents/

contemporary, dysfunctional patent landscape.[82] In other words, the core question would be whether the benefits of patents and trade secrets outweigh the costs and downside risks associated with a dysfunctional IP landscape. However, in light of the fact that "geoengineering" is a poor conceptual amalgam, a one-size fits all approach to IPRs would be grossly insufficient. The risks and governance challenges involved differ greatly from one proposal to another; similarly the relative gravity of downside IPR risks might be more for some techniques than for others. To proceed further in determining the value, desirability, and appropriateness of IPRs for CE, we need to account for these differences.

[82] *Optimum* diffusion is of course inherently normative, but would have to account for the effects of the IP regime on R&D and governance participation in developing countries.

4. Climate engineering and IPRs: Intervention-specific concerns

This section will compare the risks and tradeoffs associated with direct air capture (DAC), ocean iron fertilization (OIF), and stratospheric aerosol spraying (SAS). While in general, IPRs might carry a more acceptable risk to benefit ratio for CDR interventions than for SRM, an effective analytical framework will ultimately need to evaluate the tradeoffs associated with IPRs and CE on a case-by-case basis. In particular, the scale and distribution of potential impacts – that is whether risks and benefits will accrue globally or locally, within global commons or within national or subnational boundaries – as well as their relative intensity, will to a large degree determine how concerned we should be about IPRs.

4.1: Direct air capture (DAC)

Direct air capture offers the promise of removing CO_2[83] from ambient air and sequestering it away – whether in abandoned oil wells, in natural terrestrial geological formations, or even through industrial design and production. DAC – like most CDR schemes – would be most likely to thrive in the context of a price on carbon. Carbon pricing would provide incentives for a wide variety of actors to develop, deploy, and invest in DAC technologies, and would help foster markets for their services. Firms might benefit by buying or selling carbon credits, by reducing their net emissions (and therefore their tax burden), or by buying or selling captured CO_2 for its use as a feedstock or industrial input. Unlike its cousin-technology carbon capture and storage (CCS), DAC would have the advantage of being able to be deployed anywhere, rather than at the source of emissions. Empowered by large markets, DAC would be characterized by distributed and decentralized action. Innovation and technological diffusion in this domain could have wide-ranging economic benefits and support the transition to a low-carbon economy. Further, DAC would not require centralized planning or international agreement to determine the optimum level of sequestration – given the enormity of current and accumulated emissions, it stretches credulity to think that "too much" CO_2 could possibly be drawn down and sequestered; any amount of CO_2 removal would be positive for climatic stability.

With DAC, however, it would nonetheless be crucial to have sufficient oversight and regulation in place to transparently, independently, and robustly monitor the

[83] Or perhaps other gases. See footnote 12, p. 8.

transportation and storage of captured gases. Assuming a distributed network of DAC operations, individual leaks would not necessarily be ruinous for the climate.[84] However, they could be deadly for local communities; the primary victims of any leaks would be local.

Thus the specific characteristics of DAC give it a particular distribution of risks and benefits. Economic benefits would accrue widely to all those actors participating in DAC related activities. The climatic benefits of CO_2 capture from a given project – however small or indiscernible they might be – would nonetheless accrue globally. However, the risks associated with DAC remain profoundly local. While the technological and regulatory burden associated with widespread DAC might indeed by high,[85] as has been suggested by Hamilton and others, it would nonetheless be one that could be approached through existing local, sub-national, and national jurisdictions, in large degree through the siting and management of specific projects, and through mechanisms such as Environmental Impact Assessments.

DAC's distribution and intensity of risks and benefits (a large, widespread 'benefit constituency' and a small, localized 'risk constituency') matter both in terms of the Oxford Principles and for the relevance of IPRs. With the benefits of DAC likely to be broadly socialized and global, and with the risks being highly localized, it should be easier to manage the balance of private and public interests as per Principle 1. While "all of humanity" would benefit from DAC projects, they would not bear the risks.[86] DAC's risk/benefit distribution should also make meeting the requirements of Principles 2, 4,

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[84] Although the cumulative effects of wide-spread leakage could significantly reduce whatever discernible climatic value DAC might have.
[85] Particularly in the (perhaps unlikely) event that DAC were deployed at a large enough scale to make a significant difference atmospheric GHG concentrations.
[86] Rayner et al. (2013).

and 5 relatively straightforward. Per Principle 2, public participation in decision-making could be conducted under existing regulatory regimes, in a manner analogous to location siting for wind-farms, mining or drilling projects, or nuclear waste depositories.[87] Similarly, per Principle 4, the independent assessment of impacts could be baked in to national and sub-national regulatory and approval processes. Such an approach would satisfy Principle 5's preference for "using existing rules and institutions wherever possible."[88]

As per the discussion in Section 4, above, trade secrets and patents could pose barriers to the fulfillment of the Principles, especially Principle 3, which calls for "the prompt and complete disclosure of research plans and open publication of results."[89] Trade secrets, for example, have been identified as a barrier to transparency and legitimacy in the regulation of hydraulic fracturing.[90] Moreover, Principle 3 is really a prerequisite for both Principle 2 and Principle 4. Without disclosure, the public (or their representatives) might be unable to meaningfully participate in informed decision-making. Similarly, the independent assessment of the effects of DAC will hinge on the availability of relevant data.

However, since the impact of any downside risks would be fundamentally local, the risk of getting things wrong due to the possible malignant effects of the current IP regime need not necessarily preclude promoting IPRs as a tool to foster innovation and knowledge diffusion.

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[87] This last example is chosen deliberately to highlight that just because the risks associated with DAC would theoretically be manageable within existing frameworks does not mean that the process and outcomes would be non-contentious.
[88] Kruger (2013)
[89] Rayner et al. (2012) , Kruger (2013)
[90] Norton Rose Fulbright (2013).

Looked at another way, with direct air capture, the gravity or intensity of the "governance challenges" discussed in Section 2.2 above is relatively small. Consider the challenges associated with social lock-in. Certainly, patents and trade secrets could contribute to the creation of vested interests, impede effective regulation, and even contribute to regulatory capture. However, whatever negative effects might result from such capture, they would be fundamentally local, and bounded concretely by existing national and sub-national modes of regulation, representation, and redress. This is not to deny the possibility of pernicious risks, but rather to suggest that the mere possibility of regulatory capture and its negative effects need not automatically preclude the encouragement of IPRs as a tool to promote R&D in DAC.[91]

[91] Assuming that they can be empirically demonstrated to function to this end.

4.2 Ocean iron fertilization (OIF)

Ocean iron fertilization involves a slightly different set of considerations. Since patents and trade secrets might alternatively foster or impede innovation and knowledge diffusion, we must again consider how severe the downside risks might be given the specific governance challenges and risk/benefit distribution associated with this particular proposal.

Like DAC, commercial OIF activity seems most likely to thrive in the context of carbon markets. Even Russ George and the HSRC – with their 2012 “salmon restoration” effort – planned to cash in on carbon credits.[92] Moreover, OIF has had something of a cyclical history, wherein “scientific experiments are followed by media and commercial interest.”[93] Thus when ocean iron fertilization is perceived and/or reported on as an area of scientific interest, commercial activity in OIF increases. Thus there is good reason to anticipate further IP-related interest in OIF.

Being focused on sequestering already-emitted CO_2, it is unclear how much of an impact OIF could realistically have on anthropogenic climate change, given the sheer scale of such emissions, and the potential for negative ecological consequences from large-scale OIF activities.[94] Indeed, “studies have yet to demonstrate that ocean fertilization will work as a long-term carbon sequestration strategy.”[95] However, as the Canadian episode shows, these realities need not preclude commercial interest, since, much like DAC, the threshold for undertaking a given OIF action is not that the

[92] See e.g. McKnight, Zoe, and Hoekstra, Gordon, (24 Oct, 2012).
[93] Strong, Aaron L., Cullen, John J., and Chisholm, Sallie W. (2009).
[94] See e.g. Sagarin, Raphael et. al, (2007); Strong, Aaron, Chisholm, Sallie, Miller, Charles, and Cullen, John, (Sept. 17 2009); and Strong, Aaron L., Cullen, John J., and Chisholm, Sallie W. (2009).
[95] Bracmort, Kelsi, and Lattanzio, Richard K. (2013), p. 13.

sequestration be globally significant for the climate, but rather the expectation that it be commercially significant for the transacting parties involved. In practice, as with DAC, a large number of actors could become involved in commercial OIF operations.

In contrast to DAC, since OIF is deployed in ocean systems, interacting with dynamic ecologies, chemistry, and currents, OIF interventions could have regional and transboundary effects in addition to local ones. In particular, critics have expressed concern that "ocean fertilization will lead to ocean acidification, additional emissions of potent greenhouse gases, and reduction of oxygen to levels not habitable by certain species."[96]

Such risks are clearly transboundary in nature, and imply a scale-up from the risk/benefit intensity and distribution associated with DAC. With OIF, potential economic benefits would accrue to the transacting parties, and could be associated with more widespread economic gains if associated with carbon markets. Clearly there is also the potential for local and regional socio-ecological benefits, as was hoped for in the case of the HSRC fertilization event.[97] As with DAC, the climatic benefits of a particular intervention, while likely imperceptibly modest, would nonetheless accrue globally. Unlike in the case of DAC, however, the risks associated with OIF would not necessarily be neatly bounded by national or subnational regulatory units, nor constrained to a local scale.

Again, this has implications both for the Oxford Principles and for the relative importance of IPRs. Given the possibility of pernicious transboundary effects associated with OIF activities, the stakes are somewhat higher than for DAC. Regulating the activity

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96 Bracmort, Kelsi, and Lattanzio, Richard K. (2013), p. 13.
97 Hopper, Tristin, (18 Oct., 2013).

"as a public good," per Principle 1 is thus all the more important, since the risks associated with poorly balancing public and private interests are higher. Involving the public in decision making, per Principle 2, is of course critical, but the HSRC incident – and the transboundary nature of an activity that takes place in a commons – suggest that which public(s) should be involved is not obvious. In the Canadian case, a local community (Haida Gwai) *was* directly involved in the decision to conduct the experiment; nonetheless it was followed by regional, national, and international protests and condemnations. Principle 3 ("prompt and complete disclosure of research plans and open publication of results") is really a prerequisite for both Principle 2 and Principle 4. Without disclosure, the public (or their representatives) will be unable to meaningfully participate in decision-making in an informed manner. Similarly, independent assessment of any impacts will hinge on the availability of relevant data. Given the potential for negative transboundary impacts from OIF, the possibility that patents, trade secrets, and the vested interests they sometimes foster might impede such disclosure should give us pause. Discouraging, resisting, or restricting intellectual property claims at this scale (and even independent commercial activity) may thus make more sense than it would for DAC.

The HSRC example is instructive. In this case, important data has remained in private hands, and subject to legal dispute, casting a further shadow of illegitimacy over the entire episode. Russ George has suggested that the appropriation or disclosure of this data – which he considered to be proprietary - is damaging to his interests. Absent the timely and robust disclosure of the research plans and data,, independently assessing the full impacts of the experiment will be difficult if not impossible. Moreover, George and

the HSRC's apparent lack of transparency cost them legitimacy and social license, and understandably fueled a global backlash.

With regard to the third group of governance challenges, with transboundary ecological impacts come transboundary political risks. Poor transparency, undisclosed plans, data, and results (especially negative ones), insufficient informed consultation and participation in decision-making, and barriers to independent impact assessments could raise the specter of political violence. Without trust, perceived legitimacy, transparency, or social license, future commercial OIF activities could raise tensions among state and non-state actors in affected areas. Environmental activists could take "direct action" to stop or disrupt OIF activities, for example, requiring some type of security response. Nearby coastal states might register concerns related to seabed claims, impacts on fishing grounds, habitat, or even tourism; extreme scenarios could see coast guard or naval forces mobilized.

Some such risks may indeed be remote; moreover they may be manageable. All manner of oceanic activity involving transboundary risks (from undersea cable laying, to mineral and petrochemical exploration and production) takes place without producing claims that intellectual property rights are dangerous or inappropriate, and without necessarily provoking international tensions. Nonetheless, the greater scale and intensity of the risks associated with OIF, relative to DAC, should give us pause. In the case of DAC, IPRs are benign or innocuous; given the larger 'risk constituency,' and potential intensity of negative impacts, IPRs in OIF, especially trade secrets, should be considered to be of ambiguous value at best.

4.3 Stratospheric aerosol spraying (SAS)

Finally, we can turn our attention to SAS. Here again there is a different intensity and distribution of risks and benefits relative to DAC and OIF. Unlike the first two proposals, SAS offers no promise of sequestered carbon dioxide. Thus the economics of SAS are utterly different from the other two CE domains under consideration here; carbon markets would be completely irrelevant to the development and deployment of stratospheric aerosol spraying. Moreover, SAS demands only unilateral or minilateral action – a large number of geographically distributed actors would not be required to effect substantial changes in the global climate. Instead, a small number of actors, or even a single state could theoretically command the resources to undertake a successful SAS program; whatever 'market' might exist for SAS would thus be limited to those countries willing and able to do so..

While legitimate decision-making would require global participation, any hypothetical non-climatic economic benefits from SAS would thus be concentrated among the relatively small number of actors directly involved in any program. Moreover, while climatic benefits – and risks – would both be globalized, they would not necessarily accrue evenly, and could produce relative winners and losers. In addition to operating at a larger scale, the risk intensity associated with SAS is significantly higher than that associated with DAC and OIF. Deliberately intervening in the global climate could affect global weather patterns and regional agricultural productivity, for example.

SAS's distribution and intensity of risks and benefits set it clearly apart from DAC and OIF, and matter greatly both in terms of the Oxford Principles and for the

relevance of IPRs. With universal (if uneven) exposure to risks and benefits, it is critical to balance public and private interests (per Principle 1), to recognize that "all of humanity has a stake in the good of a stable climate," and to regulate SAS "as a public good." Similarly, per Principle 2, the potential costs and risks associated with insufficient public participation in decision-making are substantially higher in the case of SAS. The global impact of SAS will also make meaningful participation more difficult to achieve – it is not clear by what mechanism(s) we might have a global conversation about how much SAS might be ideal and under what conditions. Since any negative results would have global implications, rather than just local or regional ones, Principle 3's call for timely and thorough disclosure of plans and data is imperative; so too is the transparent, independent assessment of any impacts that Principle 4 demands. Given the scale and intensity of the governance challenges associated with SAS, achieving governance before deployment (Principle 5) is imperative, but will likely require a large degree of international coordination.

The critical point here is that – while in theory patents and trade secrets could either help or harm the fulfillment of the Principles – the downside risks are dramatically higher with SAS than with the other interventions being discussed, especially given that the barriers to achieving the Principles' aims are already high in this case. Since negative impacts would affect the global climate, and thus have a global constituency, the risk of getting things wrong due to the possible malignant effects of the current IP regime is unacceptable – regardless of whatever positive effects patents and trade secrets might offer for fostering innovation and knowledge diffusion in this domain.

This should become even clearer in looking more closely at the governance challenges associated with SAS. With regard to social and technical lock in, for example, vested interests at this scale seem unacceptable, not least because they would involve a gross imbalance between the small constituency standing to gain privately, and the global constituency bearing the burden of risk. Early or strategic patenting would be especially inappropriate, for example, not only because of the effects that it might have on innovation and knowledge diffusion, but also because we have yet to determine – as global stakeholders – that SAS is even something we actually want to undertake. Creating a vested interest in favour of a project whose value or need has yet to be fully articulated, whose uncertainties remain enormous, and whose risks would fall globally (and disproportionately on those countries least equipped to deal with climatic changes) is thus inadvisable. Regulatory capture might easily occur, given that any IP holders would likely also be experts; thus a conflict of interests could easily become embedded in the heart of any governance regime.

One plausible scenario under which vested interests and other risks could be fostered is through the pursuit of IPRs in designer particles. While much modeling and other research around stratospheric aerosol spraying has focused on using sulphur particles, David Keith and others[98] have raised the possibility of using nano-engineering or other processes to create particles that are tailored to the unique challenges associated with 'managing' solar radiation. Designer particles might offer any number of plausible benefits or characteristics; they might be designed for their albedo, for their persistence in the stratosphere, for their persistence over a particular area (with the aim of allowing regional rather than strictly global interventions), or simply to avoid risks or costs

[98] E.g. Keith, David (2010b)

associated with sulfate aerosols. In a recent interview, for example David Keith claims that "We are actively working on designs for advanced particles…that would have less ozone impact, *or even actually have a positive impact on ozone* [emphasis added]…Also, you could give them little magnetic and electrical fields that allow you some control over where they went in latitude."[99]

While engineered particles might indeed offer real advantages, testing the strength of claims such as those made by Keith (e.g. that a given particle might be beneficial for the ozone layer) could be made substantially more difficult should negative results, research data, modeling tools, or other information be hidden or restricted from policymakers, regulators, researchers, or the public out of a desire to protect intellectual property and the returns its owners expect it to bring.

Section 2.2 highlighted the "termination effect"'[100] as an oft-discussed socio-technical risk associated with CE – particularly stratospheric aerosol spraying. Relatedly, there are concerns about intergenerational justice, namely that given the time frame over which carbon dioxide can affect the climate, "using solar geoengineering to hold global mean temperature constant would thus require that its deployment be sustained for a long time."[101] In a recent paper, MacMartin, Caldeira, and Keith suggest that using SRM instead to limit the *rate* of temperature change might be a preferable approach, and one that would allow for a deliberate and rationalized ramp up and ramp down of SRM, "to balance undesired impacts from the solar geoengineering deployment against the damages associated with a changing climate." Such an approach could thus mitigate

[99] Temple, James (Dec. 11, 2014).
[100] Wherein the cessation of deployment results in a "rapid rise in global temperature that could be harder to manage than any temperature increase that would have occurred without intervention." Rayner et al. (2013).
[101] MacMartin, Douglas G, Caldeira, Ken, and Keith, David W. (2014), p. 11

against the termination effect and the intergenerational justice problem, by expanding the "range of choices" beyond "the binary choice of terminate or continue deployment," instead allowing for the "possibility of choosing to phase out a deployment at whatever rate might best reduce overall risk and damage."[102]

Such a highly rationalized approach might indeed be optimal – even necessary – however it is not difficult to imagine how patents and trade secrets related to designer particles could complicate the ability to implement it. Prior to any deployment, patents might restrict research, knowledge flows, and innovation (thus limiting the range of particle options to choose from); different competing patent-holders might market and lobby for the use of their preferred, proprietary particle; and all manner of technical and scientific information - including diagnostic tools, negative results, and risks - could be concealed as trade secrets. We might even imagine a 'proprietary blend' of particles with opaque or undisclosed health and ecological impacts – much like the composition of fracking chemicals has been treated as proprietary.[103] Once deployment begins, there would be a profit-bound, rent-seeking constituency around the continued deployment of the particle or blend, even in the face of improved alternatives, new risks, or a decision to ramp-down. Such a constituency would be prone to downplay risks, and advocate prolonging any ramp down so as to maintain their profits, in a manner analogous to the way some oil companies have sought to delay action on climate change. What's more, any litigation or contestation over IP would cast a further shadow over the integrity of decision-making and oversight processes. In short, patents and trade secrets, in particular

102 MacMartin, Caldeira, and Keith (2014), p. 11.
103 Norton Rose Fulbright (2013).

around designer particles, could foster conditions that seriously complicate rationalized decision-making and governance of SAS.

Transparency will be critical to building consensus, legitimacy, and trust around any proposed CE activity and its regulation. This is especially the case for stratospheric aerosol spraying. The threat posed by IPRs to transparency also has direct bearing on the third group of governance challenges – those involving free driving and potential security tensions among states, or even among state and non-state actors.

As noted earlier,[104] while it is tempting to imagine military deployment of climate engineering techniques, weather and climate modification got a bad name during the Cold War, particularly following revelations that the United States had undertaken a multi-year campaign of clandestine cloud seeding as a form of environmental warfare in Indochina. The United Nations Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques was drafted to prohibit future attempts to control the weather or climate.[105] Unsurprisingly, military agencies have so far been reluctant participants in discussions around CE. Given the normative and legal proscriptions against military use of environmental modification, as well as the inherent unpredictability of attempts to intervene tactically or strategically in a system as complex as the global climate, militaries are not expected to express interest in leading deployment in the near term. Chad Briggs summarizes this well: "SRM does pose security risks that are of interest to military planners and may result in security impacts, but … within the US security community the issue is so legally and politically sensitive that the US Department of Defense has no interest in pursuing concrete actions in this field." Briggs

[104] Supra note 15
[105] On this history, see Fleming (2010), especially pp. 179-187

goes on to point out that in addition to the strong legal prohibitions and “decades of negative experiences in attempting to alter environmental conditions during/around conflict,” “a general view in the US security community holds that geoengineering (and in particular, SRM) projects are not tightly controllable, and therefore are analogous in some ways to biological or chemical agents. Militaries tend to dislike platforms that are not tightly controllable and predictable.”[106]

While the US and other militaries may be reluctant to play an active role in SAS development and deployment, and perhaps even less likely to deliberately deploy SAS with strategic or tactical goals in mind, the greater risk may in fact be associated with miscommunication, uncertainty, misperception, misattribution, and poor transparency. Breakdowns in foreign relations and failures of foreign policy are often associated first and foremost with failures of information, understanding, and expectation. It is for this reason that confidence-building measures have been deployed around the world – to widen the margin of error among conflict-prone states by clarifying threat perceptions and policy postures, and reducing uncertainty and the risk of miscommunication, misinterpretation, or incorrect attribution.

To the extent that intellectual property claims in SAS diminish transparency, they could raise security risks, notably by eroding trust in the legitimacy, credibility, robustness, and sufficiency of decision-making/deliberation, deployment, disclosure, and assessment. Given the climatic and cultural significance of any SAS program, as well as its wide-ranging but differentiated impacts, these aspects of governance are almost certain to be politicized in any case; avoiding further undue politicization and distrust due to poor transparency and perceived conflicts of interest should be a top priority. This is

[106] Briggs, Chad (2013, Oct. 10).

particularly the case given the likelihood that extreme weather events or other disasters could be blamed by states or non-state actors on any intervention. Should Pakistan experience unusual flooding, for example (likely under conditions of climatic instability in any case), it might be preferable that an American company with IP interests not be seen to have unduly influenced decision-making and risk assessments. Moreover, it should be noted that the most vocal non-state opponents to "geoengineering" – those who adhere to the Chemtrails conspiracy – are already fixated on patents as evidence of malicious intent.[107] The key takeaway here is that the mere *perception* of conflicts of interest, illegitimacy, or poor transparency can be enough to sow discord and distrust, thereby raising the likelihood that governance will become unduly politicized, and increasing the risk of conflict.[108]

[107] Supra note 81
[108] In Vidal, John (2012), David Keith is quoted to this effect: "Even the perception that [a small group of people has] illegitimate influence [is] very unhealthy for a technology which [sic] has extreme power over the world."

5. Logics of appropriateness: Making sense of discomfort around IPRs

Thus far, this paper has suggested that (1) IPRs are in general of ambiguous value for innovation and knowledge diffusion and (2) the relative acceptability of the risk associated with IPRs will depend on the characteristics of the intervention in question, including the scale, intensity, and distribution of risks, benefits, and governance challenges associated with it. So far, the framework to evaluate the advisability of IPRs in CE thus has two dimensions: an empirical dimension (what is the most effective way to incentivize innovation and knowledge diffusion?) and a more theoretical dimension (for a given intervention, what are the scale, intensity, and distribution of risks that are likely to occur?). This section will add a third dimension by arguing that -- given the divergent risk profiles associated with different interventions – the advisability of IPRs is also normative, and a function of the *appropriateness* of introducing private interests and market logic to the governance of interventions whose risk profile varies greatly from one to the next. To fully account for the concerns that many commentators have expressed around IPRs in CE, and to build an effective framework approach to resolve them, we must engage directly with this normative dimension. It will be useful to first situate this discussion the context of broader changes in international relations, global governance, and the global political economy.

The late stages of the 20th century bore witness to, depending on one's periodization, the birth or resurgence of what is widely referred to as globalization.[109] Characterized in large part by an increase in the intensity, speed, density, and volume of flows of people, information, capital, and goods, late-20th century globalization also

[109] See Scholte, Jan Aart (2005), Esp. Ch. 2 "Defining Globalization."

coincided with and helped to propel a dramatic reshaping and reconstitution of public life and governance.[110] In short, the state, facing complex new transboundary challenges and limited resources, has seen its role change and in many cases recede relative to the logic and institutions of the market. Non-state actors and international organizations have also assumed growing importance in the ordering and regulation of public life generally, and in global environmental governance in particular.[111] As Jan Aart Scholte argues, "a move away from territorialism in geography has, not unsurprisingly, unfolded together with a move away from statism in governance … governance in the more global world of the twenty-first century has become distinctly multi-layered and trans-scalar. Regulation occurs at – and through interconnections among – municipal, provincial, national, macro-regional and global sites. No single level reigns over the others … Instead governance tends to be diffuse, emanating from multiple locales at once, with points and lines of authority that are not always clear."[112]

This analysis requires a conceptual move beyond statist IR approaches such as the regime theory famously deployed by Keohane and Victor, among others.[113] While states undoubtedly continue to pursue and assert their interests through international institutions, Betsill and Bulkeley point out that state-centric models such as regime theory cannot sufficiently account for contemporary global environmental governance, and tend to "overlook the emergence of network forms of organization where institutional relationships may bypass levels of governance, taking place directly between the local and the international" (p. 146). In a similar vein, Jonas Meckling convincingly suggests

[110] Scholte (2005), Chapter 6 "Globalization and Governance: From Statism to Polycentrism."
[111] See e.g. Ruggie, John Gerard (2004).
[112] Scholte (2005), p. 186.
[113] Keohane, Robert O., and Victor, David G. (2011), pp. 7-23.

that it would be difficult to account for the rise of carbon trading as a key instrument of global climate governance, for example, without considering the interactions of transnational business coalitions with environmental groups and policy makers operating at and across multiple scales of activity.[114] Finally, Peter Newell, in calling for a critical political economy approach to global environmental governance, argues that non-traditional sites of governance, policymaking, and power must also be accounted for. In particular, he observes that "non-environmental regimes, those governing trade, production and finance … are critical to the possibilities of effective environmental governance."[115]

The results of this reshaping of governance and the ascension of the private sphere have been mixed. While a greater number of stakeholders have become involved in governance processes and decisions, this re-ordering of public life has also produced contestation and anxiety, notably in the face of diminished transparency, and more opaque lines of agency and accountability. Thus, for example, while state-led efforts to address climate change through the Kyoto Protocol have largely failed to yield results, transnational business coalitions and city-networks have demonstrated growing capacity and achieved increasing influence within the broader governance space.[116]

Average citizens, however, their agency limited to domestic electoral politics,[117] are poorly equipped to influence or even comprehend structural constraints and decision making processes and effects that are now widely found above or beyond the state. If we accept that accountability and transparency are cornerstones of legitimacy in governance,

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114 Meckling, Jonas (2011).
115 Newell, Peter (2008) p. 509.
116 On city networks, see Betsill, Michele M., and Bulkeley, Harriet (2006). On transnational business coalitions, see e.g. Meckling, Jonas (2011).
117 Indeed even more limited in non-democratic and quasi-democratic regimes.

then much global governance today involves a democratic deficit for average citizens.[118] Diane Stone describes this enlarged governance space as a "global agora" to which access is highly uneven, favouring elite and expert communities. "The vast majority of citizens of nation-states," Stone writes, "are uninformed about these policy venues and even if interested, face significant obstacles to 'raise their voice.'"[119]

These trends – in particular the ascension of private actors and the market in the shaping of public life – are of concern to the political philosopher Michael Sandel. In his recent book *What Money Can't Buy: The Moral Limits of Markets*, Sandel argues that over the past thirty years, the "logic of buying and selling" has expanded beyond trade in material goods to increasingly govern "the whole of life," culminating in the "era of market triumphalism" that preceded the 2008 financial crisis. Sandel argues that greed is "at best, a partial diagnosis" for the crisis; he suggests that we also consider the impact of the "the expansion of markets, and of market values, into spheres of life where they didn't belong." In particular, Sandel points to the "reach of markets, and market-oriented thinking" into the regulation and allocation of "health, education, public safety, national security, criminal justice, environmental protection, recreation, procreation, and other social goods" as "unheard of thirty years ago." That we now take such developments largely for granted is of concern for two reasons, Sandel suggests. The first has to do with inequality: "In a society where everything is for sale, life is harder for those of modest means. The more money can buy, the more affluence (or the lack of it) matters." The second reason is more intangible, Sandel suggests. It has less to do with "inequality and fairness" and more to do with the notion that "putting a price on the good things in life

118 On accountability and civil society, see Scholte, Jan Aart (2011).

119 Stone, Diane (2013), p. 20.

can corrupt them. That's because markets don't only allocate goods; they also express and promote certain attitudes towards the goods being exchanged…Sometimes market values crowd out nonmarket values worth caring about."[120]

In assessing the appropriateness of IPRs in CE, it is may be helpful to engage directly with this normative dimension. I submit that – beyond the clear empirical and theoretical concerns - the discomfort around IPRs in CE is a reaction against the reordering of public life, the global economy, and global governance on the one hand, and also (relatedly) against a perceived technological approach to a fundamentally moral crisis on the other. Recall, for example, Hamilton's protest that "there is something deeply perverse" in deliberate climate interventions "when we could just stop burning fossil fuels."[121] Recall too the "underlying feeling of abhorrence,"[122] some associate with the notion of climate engineering. Perhaps most telling is Hamilton's concern that "we are approaching a situation in which international efforts to protect humanity from climate catastrophe could depend on whether or not one company wants to sell its intellectual property."[123] In the context of the present discussion, the alarm he raises seems to have less to do with empirical risks of a firm extorting the world for licensing fees, and more to do with the sense that there is simply something wrong with

[120] Sandel, Michael (2012), See esp. pp. 7-16.
[121] Hamilton (2013) pp. 49-50. This observation certainly applies to direct air capture (DAC), and to carbon capture and storage (CCS). Other techniques, such as OIF or limestone spreading would similarly require large-scale and continuous effort to make so much as a dent in ongoing emissions and ocean acidification. Hamilton's comments hint not only at the technical challenges associated with CDR, but also at the normative concerns that motivate much discomfort with the idea of climate engineering. The common protest '*Why not simply address the challenge directly, and cut emissions?*' is bolstered by the moral sense that to do otherwise is to fundamentally avoid responsibility for a problem of our own creation.
[122] MacMartin et al (2013)
[123] Hamilton (2013), p. 80.

introducing property relations – and a potential conflict of interests – when the fate of the world is at stake.

Given the wide-ranging moral dimensions of the climate challenge (from differentiated global responsibilities and impacts to intergenerational justice), the ethical-normative challenges associated with some CE proposals, and the Oxford Principle preference for regulating CE as in the public interest, we would do well to heed Sandel's advice and regard the climate as the ultimate public good, and be wary of introducing relations that might corrupt attitudes toward it.

When discussing the Ethical-Normative challenges associated with 'geoengineering,' it is often SRM techniques such as aerosol spraying that come to mind. This is particularly the case because, while both DAC and OIF might be deployed locally or regionally in a relatively bounded fashion, SAS would have a global impact. It's not clear that DAC would involve a profound and explicit reframing of our species' relationship with the planet; ongoing SAS however seems much more likely to provoke an and "open a new chapter in humanity's relationship with the earth."[124] The deep uncertainties and unknowns associated with the technique, the global scale of SAS' impacts, and the potential for small number of actors or a single state to produce them gives SAS a cultural gravity and political significance that is not shared by interventions of a smaller scale and intensity.

Moreover, where risks are localized and of relatively lower intensity, uncertainty is marginal, and avenues for redress and grievance exist, we might be less concerned about allowing market mechanisms and market thinking to influence the trajectory, development, or even the regulation of CE. In the case of DAC, for example, the nature

[124] Keith, David (2010a), p. 495.

of the intervention suggests that existing political units will effectively bound its effects, with well-established (if imperfect) mechanisms for public consultation, regulation, and redress. When scaling up to the level of impact and intensity of risk associated with SAS, however, such constraints and mechanisms of redress are absent – even irrelevant. Introducing market thinking in the form of property relations, and inviting the perverse incentives, vested interests, motivated reasoning and so on that are often associated with the dysfunctional IP system thus fails a *normative* test, by giving the private sphere too much potential influence – with enormous potential consequence - over the ultimate public domain.

It bears mentioning as well that such normative concerns can feed back onto the empirical effects of patents and trade secrets on innovation and knowledge diffusion. Normative discomfort around IPRs can reduce public trust in the trustworthiness of researchers and their projects, and the legitimacy, independence, and effectiveness of governance processes. In short, normative concerns are constitutive of social license. We need look no further than the failed SPICE project to see that such concerns can impose real constraints on the ability to conduct research and maintain public trust.[125] If we are serious about promoting research in SAS and other CE domains, maintaining such trust by engaging directly with this normative dimension – and resisting corrupting forces – will be essential.

[125] Cressey, Daniel (2012).

6. Conclusions and future research

The results of the framework developed in this paper – as applied to DAC, OIF, and SAS – are summarized in the table below:

	DAC	OIF	SAS
Scale / intensity of risk	Local / Low	Local-Regional / Medium	Global / High
Normative appropriateness of introducing IPRs	Benign / Innocuous	Ambiguous	Inappropriate
Effect of IPRs on research, innovation, knowledge diffusion	Ambiguous / Unknown	Ambiguous / Unknown	Ambiguous / Unknown

Table 1: A framework approach to evaluating the advisability of IPRs in DAC, OIF, & SAS

In short, the desirability of IPRs in CE is a function of the intensity and scale of the risks posed by a given intervention, the normative appropriateness of introducing additional risks through private property relations, and the empirical effects of patents & trade secrets on innovation and knowledge diffusion.

In the case of direct air capture, for example, climatic benefits would accrue globally and economic benefits could accrue at multiple scales (e.g. local jobs and companies, regional carbon markets). However, the greatest risks – in the form of gas

leaks - would be primarily local, and within the regulatory bounds of national governments. Given the bounded scale and intensity of potential impacts, there does not appear to be a case to resist patents or trade secrets on any but empirical grounds. The question for DAC, then, is whether such IPRs will function as the best mechanism to foster the innovation and knowledge diffusion that would serve the public good.

Ocean iron fertilization more obviously poses transboundary risks to commons areas, ecosystems, and fisheries. Indeed, this may help to explain the greater discomfort that has been associated with such activities relative to the apparent enthusiasm associated with DAC.[126] Discouraging, resisting, and even restricting intellectual property claims at this scale (and even independent commercial activity) could make sense, but will require further study and ongoing evaluation. For now, especially in light of the HSRC episode, IPRs in OIF are of ambiguous value, at best.

Finally, in the case of stratospheric aerosol spraying, both risks and benefits could accrue globally – or indeed regionally. Nonetheless, in contrast to DAC, where a large number of actors acting over a widely distributed area might plausibly be involved, with SAS a unilateral or minilateral action would have global consequences. Under such circumstances, profit seeking – and introducing property relations - seems problematic and incompatible with Sandel's moral argument. Moreover, the potential risks associated directly with IPRs would have their greatest consequence with this type of activity and scale of action. Commercial activity in general and IPRs in particular could exacerbate the risk reward structure in a wholly undesirable way, by instituting the incentive and motivation for private commercial benefit, while deployment risks remain globally socialized.

[126] Dvorsky, George, (Oct 9, 2012).

Thus the higher we move up this scale towards commons areas, and in severity and dispersion of potential risks and unintended consequences, the less appropriate are IPRs for CE – whatever their empirical effects on innovation and knowledge diffusion.

As for this last question, the relationships between patents and trade secrets on the one hand, and innovation and knowledge diffusion on the other remain contested and ambiguous. Indeed, the relationship between innovation, competition policies, and intellectual property rights remains not only empirically contested, but also largely under-theorized,[127] thus more research is required. IPRs can – in theory - aid in the fulfillment of the Oxford Principles' goals, to the extent that they foster innovation, transparency, and knowledge diffusion. Where IPRs function well towards these ends, restrictions could impose costs, limit the transmission of knowledge, and impede innovation. However there are also numerous downside risks and pernicious effects associated with what is widely described as a dysfunctional, inefficient, and increasingly global IP regime. These include restricting knowledge flows and innovation, the concealment of negative results, strategic patenting, and the development of vested interests and rent-seeking behaviour.

Where CE proposals pass the tests posed by the first two framework criteria, the advisability of IPRs thus becomes a purely empirical question – namely "do patents and trade secrets help to foster or impede research, innovation, and knowledge diffusion?" Answering this question will demand further study and ongoing monitoring as interest in CE continues to develop and more data become available, in particular by those scholars who have expertise in the study of innovation and knowledge governance. This is especially the case given that CE R&D is still in a relatively early stage, given that IP

[127] Burlamaqui (2012), p. 20.

filings in CE have been relatively limited so far,[128] and given the ambiguous findings on the aggregate relationships between IPRs, innovation, and knowledge diffusion. Indeed, it is critical to expand the research program on IP and CE, and monitor the impacts of patents and trade secrets on funding, research, knowledge diffusion, technological development, and public trust. In doing so, it will be especially important to disaggregate 'geoengineering,' and pay attention to the widely differentiated impacts of IP claims for different activities. Ultimately, it will be difficult to evaluate the full impact or consequences of IPRs for particular CE sub-fields without an assessment of what types of IP claims are being made, by whom, in what quantity, and with what motivations. Some researchers have begun contributing very helpful preliminary work in this area, but ongoing monitoring, including bibliometric studies, will be required to keep abreast of highly dynamic developments, and to deploy effective anticipatory governance.[129] Indeed, "only detailed study of the industry of concern has the possibility of uncovering reliable relationships between innovation and industry behaviour."[130]

It is the author's hope that -- in the early absence of such studies -- the framework developed in this paper will serve as an effective guide to help clarify the conditions under which IPRs might be desirable or not, to help determine whether they should recommended or resisted, and to help place concerns about patents, trade secrets in their proper context – thus clearing the air on CE and intellectual property rights.

[128] Oldham, P. et al. (2014).
[129] Oldham, P. et al. (2014)
[130] Cited in Burlamaqui, (2012) p. 14.

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