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OPINION

Intellectual property policies for solar geoengineering

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Governance of solar geoengineering is important and challenging, with particular concern arising from commercial actors' involvement. Policies relating to intellectual property, including patents and trade secrets, and to data access will shape private actors' behavior and regulate access to data and technologies. There has been little careful consideration of the possible roles of and interrelationships among commercial actors, intellectual property, and intellectual property policy. Despite the current low level of commercial activity and intellectual property rights in this domain, we expect both to grow as research and development continue. Given the public good nature of solar geoengineering, the relationship between the public and private sectors would likely assume a procurement structure. Innovative policy approaches to intellectual property and data access that are specific to solar geoengineering are warranted. These current circumstances also present opportunities for the development of policy and norms that might soon be lost. We consider some possible approaches, and recommend a bottom-up, primarily nonstate, voluntary "research commons" for patents and data that are related to solar geoengineering. This would facilitate information sharing and limit data fragmentation and trade secrecy. It would also provide an incentive for commons members to pledge to limit some forms of intellectual property acquisition and to assure access on reasonable terms, thereby limiting the need for enforcement. This should help reduce downstream barriers to innovation and to encourage the potential development of technologies at reasonable cost. Such a research commons might also catalyze the adoption of best practices in research and development.

This article is categorized under:
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1 | INTRODUCTION

Solar geoengineering is a set of proposed means to block or reflect a small portion of incoming sunlight in order to counteract and reduce anthropogenic climate change. Largely in response to disappointing abatement of greenhouse gas emissions, interest and research in solar geoengineering have risen steadily over the last decade. There have been, among other things, authoritative reports from the Royal Society and the US National Academies (McNutt et al., 2015; Shepherd et al., 2009), an international model intercomparison project (Kravitz et al., 2015), and a recommendation for publicly-funded research by the US Global Change Research Program (2017). Preliminary outdoor experiments of solar geoengineering techniques have been proposed and, in at least a couple cases, funded.

The governance of solar geoengineering has been an important yet challenging issue, with projects both inside and outside of academia exploring opportunities and impediments. As it is presently understood, solar geoengineering would necessarily modify the global climate, yet the direct financial costs to implement some forms of it appear to be low enough that a single nation could do so, at least in principle. Consequently, the governance discourse has focused primarily on how states could cooperate in decision-making and avoid conflict regarding solar geoengineering implementation. Much solar geoengineering governance scholarship has been grounded in international law, while some civil society initiatives such as the Carnegie Climate Geoengineering Governance Initiative focus on intergovernmental institutions and, to a lesser degree, national policy. Furthermore, as discussed below, various policies have been proposed to restrict intellectual property (particularly patents) in or otherwise to assure public access to solar geoengineering technologies.

The possible roles of private actors in the research, development, and potential implementation of solar geoengineering technologies have received less sustained attention. The spectre of nonstate actors implementing solar geoengineering was invoked early on (Victor, 2008), but has largely been rejected as unlikely (Parson & Ernst, 2013). More typical roles for private actors in contexts of proposed and emerging technologies are those of innovators and providers of technology goods and services. The incentives for potential recoupment of investments to develop these goods and services are substantially, though not entirely, shaped through policies governing intellectual property (hereinafter "IP," and here meaning principally patents and trade secrets). Yet a skepticism, if not an outright aversion, to the prospect of commercial involvement in solar geoengineering exists in discussions of its governance (Rayner et al., 2013; Shepherd et al., 2009). For example, an early planned field test of solar geoengineering technologies was cancelled because of, among other reasons, concerns that one of the proposals' reviewers was a coapplicant on a relevant patent (Marshall, 2012). (Of course, such potential conflicts of interests are problematic even in domains in which commercial activity is widely accepted.)

Nevertheless, we believe that the private sector will likely play a growing role in solar geoengineering. In fact, most states usually do not directly undertake endeavors of such a scale themselves, but rely on the private sector for research, development, production, and services, even when the government ultimately procures the goods and services and decides how they are to be used. Governments in many jurisdictions often encourage private development through subsidies and by allowing grant recipients and contractors to own IP covering technologies that they develop with taxpayer-supported funds. Furthermore, the private sector arguably *should* play a role in solar geoengineering research and any subsequent development and possible implementation, as the private sector is the primary source of valuable innovations in many devices, materials, techniques, and services that might be necessary or useful for any development and implementation of solar geoengineering. Next we consider approaches to IP policy for solar geoengineering innovation (broadly understood to include all technologies that ultimately might be needed for potential implementation, including general purpose technologies not specifically intended for use in solar geoengineering, although many other technologies might be needed for the research and development of solar geoengineering).

2 | THE PRESENT AND POSSIBLE FUTURE IP AND COMMERCIAL LANDSCAPE

Any consideration of IP policies must take the specific characteristics of solar geoengineering into account. In many ways, it is not a typical emerging technology. Indeed, at first glance, as a technology that governments would likely have authority concern its possible implementation, it might be unclear why private actors would become involved in solar geoengineering at all. After all, solar geoengineering research, development, and implementation would be public goods, not necessarily in a normative sense but in the economic sense of providing the nonexcludable and nonrivalrous benefits of expected lessened climate change. Because the generator of knowledge regarding solar geoengineering and its implementer cannot exclude those who would benefit, it cannot directly charge for this. Due to this imbalance in market incentives, public goods, such as highways, are typically provided by the state or through various kinds of private charitable contributions (Sarnoff, 2016).

Consistent with the public good nature of the technologies, our research indicated that there has been little solar geoengineering patenting activity to date (Reynolds, Contreras, & Sarnoff, 2017). In an examination of U.S. Patent and Trademark Office and international public records, we found 33 international patent and patent application families that were at least closely related to solar geoengineering. Of these, 13 had been abandoned, 5 had expired, and 17 were related to space- and surface-based techniques, which are generally regarded as prohibitively expensive, of limited capacity, and/or otherwise infeasible. That left only six patent families that appeared relevant to solar geoengineering exploitation, four of which were issued and two of which were then pending as applications. Five of these patents and applications concerned stratospheric aerosol injection, and one application related to marine cloud brightening. Even some of the aerosol injection patents were of questionable relevance. Through informal and limited anecdotal sources, we also found that there presently is a culture and practice among solar geoengineering researchers of sharing data freely, and little evidence that these researchers kept data or know-how to themselves or took protective measures to maintain trade secrecy in the data and know-how.

There are other indications that solar geoengineering research is proceeding in a publicly oriented manner. Governments and philanthropists—not investors (although there are some minor exceptions)—appear to be funding the vast majority of research. Moreover, solar geoengineering research is being carried out almost entirely at universities, not at private firms. We believe that this current open condition presents a unique opportunity to consider and perhaps enact innovative IP and data sharing policies and to develop important norms for solar geoengineering-related knowledge and technologies.

However, this rare opportunity might not persist, particularly if and when commercial actors begin to take a greater interest in solar geoengineering. Despite its public good character, there might be substantial opportunities to profit from these technologies. We believe that large-scale research, development, and potential implementation of solar geoengineering are most likely to assume a monopsony (or oligopsony) procurement structure, as it has in the national defense and transportation sectors. In these contexts, the government and other public bodies make major operative decisions while commercial actors provide goods and services according to governmental specifications. A procurement arrangement is evident in the above-mentioned proposal for an outdoor solar geoengineering experiment, in which researchers plan to contract with a private provider of stratospheric balloons (Keutsch Research Group, n.d.). Looking toward possible implementation, estimates of the direct financial cost of global solar geoengineering deployment are approximately US$ 25 to 50 billion annually (Moriyama et al., 2016); monitoring and related activities would increase the total annual spending. This implies that providing technology, materials, and services could be a moderately sized industry generating significant profits. Yet the opportunity for developing IP and data sharing policies for solar geoengineering in a culture of open research might be limited. An open debate is thus urgent, and we hope to catalyze it.

3 | CHALLENGES

Other aspects of solar geoengineering are relevant to possible IP and data sharing policies. First, any implementation would inherently have transnational effects. Not only would these effects be felt worldwide, but we also expect research and innovation to be collaborative and to transfer know-how and technologies across borders. Although there are instruments of international coordination, harmonization, and dispute resolution, the core requirements and competencies of IP and data access law remain within national jurisdictions and with their state regulators. Moreover, states might be unlikely to fill the funding and regulatory roles that they could and should have. This is because government legislators and regulators have been reluctant to wade into the solar geoengineering discourse beyond granting a few small pools of funding, and have yet to develop national laws specific to solar geoengineering. The current state of national control with limited involvement seems clear, and likely to persist for some time: elected officials and the appointees who report to them have little incentive to address an issue that is both controversial and (for some) seemingly nonurgent. In particular, progressive proponents of action to control climate change may be concerned about undermining efforts to reduce carbon emissions and might worry about alienating some of their green base, while those who are more skeptical of climate change in principle are unlikely to act at all.

A second difficulty for IP and data access policies is that there is no clear line between, on the one hand, research and innovation within solar geoengineering and, on the other, activities outside of the field. In the case of research, the primary physical means of reflecting incoming sunlight—aerosols and clouds—are two of the greatest sources of uncertainty in climate change research more generally. Research in these domains will inform that of solar geoengineering, and vice versa (Wood, Ackerman, Rasch, & Wanser, 2017). Likewise, inventions developed in contexts outside of solar geoengineering would have applications therein, and those that seem exclusive to solar geoengineering would have uses elsewhere. For example, a major challenge for marine cloud brightening is developing nozzles that can spray an extremely fine mist of salt water without clogging. Not coincidentally, developers of inkjet printers are involved in this research (Krieger, 2015). Thus, one can expect a range of "dual use" inventions across solar geoengineering technologies, such as pumps, conduits, materials, and monitoring equipment.

4 | SOME POLICY OPTIONS

Other scholars have made proposals about IP and data access policies for solar geoengineering that we have considered. We focus below on IP policies. First, some have suggested that patents on solar geoengineering inventions should not be permitted at all (Chavez, 2015; Mulkern, 2012; Parthasarathy, Avery, Hedberg, Mannisto, & Maguire, 2010). Because IP law is within states' purview, to implement this recommendation, many policymakers and legislators in multiple jurisdictions would need to take coordinated action within a short amount of time. Although an international agreement is possible in principle, agreeing upon one would be difficult, protracted, and uncertain. Furthermore, such legislative and administrative limitations would likely both reduce the incentives to innovate as well as push data and technology inventors either to move their efforts to more patent-friendly jurisdictions or to rely on trade secrets, which in turn would reduce transparency and could impede innovation. Finally, as indicated above, determining which inventions are sufficiently related to solar geoengineering to be excluded from patentability would remain difficult to determine ex ante. As a result, we doubt the efficacy of such proposals.

Second, other legal scholars have suggested that governments should, in the case of important inventions with environmental applications, consider the exercise of march-in rights for patented inventions funded in part by the government, as well compelling private licensing if the need to do so develops. In contrast, one of us has encouraged clarifying ex ante the conditions that would warrant the exercise of march-in rights in regard to climate change technologies (which includes solar geoengineering), precisely to avoid the fractious disputes and reduction of incentives that ex post compulsory licensing would engender (Sarnoff, 2011). To the extent that governments themselves need to use the technology, moreover, they already might (as in the United States) have a statutory right to do so either without payment (for government-funded inventions) or with reasonable compensation (if no government funding was involved) (35 U.S.C. §§ 201 et seq.). However, it is more difficult for governments to compel transfers of data and knowledge maintained as trade secrets, particularly if that knowledge remains uncodified.

In the case of solar geoengineering, governmental authority to mandate production and use of technologies subject to IP rights at no or reasonable cost could serve important social goals. If the private owners of patents or trade secrets covering inventions essential to research, development, or possible implementation refuse to provide or license them, or demand unreasonable terms or impose unreasonable prices, and solar geoengineering appears necessary to reduce climate risks, then governments could ensure that these inventions or know-how could be utilized at a reasonable cost. However, we believe that such governmental overriding of voluntary licensing and production should be measures that are taken only when the conditions in the private market warrant them, which should (we hope) be relatively rare, particularly given a monopsony (or oligopsony) market for these technologies and services. In fact, march-in has thus far not been used to address unreasonable pricing and, absent serious competition concerns, compulsory licensing has been relatively rare. As a result, we do not believe that government retained rights, march-in rights, or compulsory licensing will generally be necessary in the field of solar geoengineering, although we do recommend that governments should clarify the conditions for using march-in or compulsory licensing authority before any need to exercise it arises (while noting that governments would retain that authority even if they fail to clarify).

Third, patent pools have been put forth as an approach to managing IP for solar geoengineering (Chavez, 2015). Patent pools are legal arrangements among patent holders to offer access to their patents in a coordinated fashion. These are usually managed in a centralized manner, and potential licensees can obtain access to the patents as a bundle. Although in some cases patent pools can avoid or mitigate the impact of so-called patent thickets, this might not be the optimal tool for solar geoengineering. In particular, serious antitrust and competition issues can arise when a patent pool includes patents covering technologies that are substitutes for one another (e.g., marine cloud brightening and stratospheric aerosol injection), as has been documented in many cases (US Department of Justice & Federal Trade Commission, 2007). Because solar geoengineering is at an early stage, the most effective technological approach(es) remains uncertain. Thus, multiple patent pools would be required to address the variety of different techniques under consideration. Moreover, the early formation of pools covering certain technologies could encourage so-called lock in to a set of technologies that might ultimately prove to be suboptimal. Finally, creating and managing such pools are difficult and expensive activities. Accordingly, while we appreciate the potential for patent pools to facilitate innovation and development and to reduce costs of any implementation, we believe that it is premature to consider their use as an effective governance model for solar geoengineering.

Fourth, some solar geoengineering researchers have engaged in defensive patenting and publishing. Under these approaches, researchers either obtain patents or publicly disclose inventions not to generate revenue, but in order to keep others from patenting them or from treating them as trade secrets. For example, one solar geoengineering researcher who holds a relevant patent said that he applied for it because "We wouldn't want ExxonMobil or Shell to have control" (Marshall, 2012). In addition, scientists publish their discoveries in order to establish prior art so as to defeat subsequent patents that build on the technology (Keith, 2010). These defensive activities can create obstacles to the issuance of patents that the researchers consider to be undesirable, or at least undesirable if particular actors were to hold them. Although there is no convincing reason for such activities to stop, there are reasons to be cautious about the benefits of defensive patenting and publishing. For example, obtaining defensive patents can open researchers to accusations of personal financial interests in the execution and results of controversial research. (In fact, as noted above, a reviewer's ownership of a patent contributed to the cancellation of a proposed solar geoengineering field experiment.) Furthermore, defensive publication might not necessarily preclude, but rather assist the development of improvements or new inventions patented by the others whom the defensive publisher wishes to keep from patenting. These prior subsequent patent holders would no longer be subject to having to cross-license their inventions on reasonable terms. Finally, even if defensive patenting and publication are effective in blocking subsequent patenting, they might drive the developers of sequential innovations toward trade secrecy. Thus, these methods run the risk of creating a heterogeneous IP landscape that could ultimately hinder research.

5 | OUR PROPOSAL: A RESEARCH COMMONS

Given these considerations, we make four recommendations regarding IP and data access governance for solar geoengineering (Reynolds et al., 2017). First, we propose the formation of a "data commons" that would assure that solar geoengineering research data would be made publicly available free of charge for further solar geoengineering research, development, and possible implementation, and that any subsequently generated data by a person or entity who accessed the research commons would be added to the commons. Such a data commons would be maintained using uniform formats and metadata tagging in order to permit other researchers to use it readily. It could employ—but need not require—centralized management of the data. Further, we propose broad public, public-interest, and commercial sector involvement in the commons' management, and suggest that one or more intergovernmental institutions, such as the UN-affiliated Working Group on Coupled Modelling of the World Climate Research Program, become the data repository and coordinator of the commons' standards.

Once established, the benefits of gaining access to the data commons would offer an incentive for both noncommercial and commercial researchers to agree, as conditions of access, to contractual obligations to share their own data and to adopt the IP pledges discussed below. Particularly if the data commons were established at an early stage of solar geoengineering research, it could contain most of the valuable research that would be developed, and its value would continue to expand over time. Thus, it could induce commercial interests as well as the current university researchers to participate in the data commons, rather than to seek more restrictive, proprietary approaches to the research, development, and potential implementation of solar geoengineering technologies. Early and widespread participation by researchers not only would strengthen the incentive to participate, but also would help to establish important norms in the scientific and commercial communities. These include sharing, openness, and employment of reasonable licensing policies—norms that could then propagate beyond contractual obligations, helping to avoid some of the concerns described above.

The second component of our proposal is a formal pledge that would be made by solar geoengineering researchers and other actors who wished to access data from the research commons (Contreras, 2015). It would thereby establish a community of pledgors that, we hope, could largely avoid the challenges of restrictive or costly access to data and to the technologies needed for solar geoengineering research, development, and potential implementation described above, while avoiding the need for state interventions and antitrust concerns associated with patent pools. Patent pledging has become increasingly common, providing a flexible mechanism to address concerns over the potential that large quantities of patents in an emerging field may stymie innovation in that field (Contreras, 2015). Examples of such pledging communities range from the Open Innovation Network (OIN), an affiliation of more than a thousand firms seeking to promote the utilization and adoption of open source code, and, in the green technology space, the Eco-Patent Commons, in which 13 large firms pledged approximately 250 patents over an 8-year period.

The pledge would have nine tenets:

1. The pledge would apply to all patents held by the pledgor that cover technologies necessary to research, develop, or implement solar geoengineering, as well as to any other patents resulting from the pledgor's solar geoengineering research, development, or implementation.
2. The pledgor would commit not to assert covered patents against other pledgors in the latter's legitimate solar geoengineering research, development, and implementation activities.
3. As an alternative to the above, pledgors could license their patents nonexclusively to other pledgors at reasonable royalty rates for the latter's legitimate solar geoengineering research and development activities.
4. The pledgor would make any future sales or transfers of the patent conditional upon acceptance of the pledge by the recipient.
5. The pledgor would produce and makes available solar geoengineering research and development data in a manner consistent with international standards, as well as providing such data to back to the data commons.
6. The pledgor would similarly commit to share solar geoengineering-related data with other legitimate solar geoengineering researchers (if those researchers could not for some reason access the data from the commons).
7. The pledgor would cooperate with international efforts to monitor and assess patents related to solar geoengineering, such as those described below.
8. The pledgor would submit results of solar geoengineering research to peer reviewed scientific journals, preferably with open access.
9. The pledgor would commit not to not retain or assert valuable technical information or know-how regarding solar geoengineering as trade secrets.

Significant institutional support would be necessary for launching the pledge as well as for subsequent administration. Given the reluctance to date of governmental bodies to engage with solar geoengineering technologies, non- and quasi-governmental scientific bodies such as the Royal Society, the American and European Geophysical Unions, the American Association for the Advancement of Science, and the International Council for Science, as well as private research funders, might be in the best position to develop, support, and maintain a solar geoengineering IP pledge community. Such bodies are also well situated to consider the relationships of IP considerations to state regulation of the conduct of research. There should be mechanisms within the community to permit incorporation of other partners, such as government funders, state agencies, research institutions, scientific publishers, intergovernmental organizations, nongovernmental organizations, and for-profit private actors into the administrative structure. There should also be a path toward increasing national- and inter-governmental regulation and control of an administrative body and the pledge community.

The third component proposes that national patent offices to be vigilant in examining patent applications relating to solar geoengineering, as well as monitoring solar geoengineering-related trade secrets (to assure compliance within the pledge community and to assess effects of any trade secrets outside of it), and we recommend the establishment of an international solar geoengineering patent and trade secrecy monitoring panel. This is because we have concerns regarding the potential future accumulation and enforcement of patents or trade secrets, particularly given the early stage of the field and the scarcity of prior art. Our concerns are especially acute with respect to the development of early, broad solar geoengineering-related patents, such as patents claiming uncreative applications of newly discovered solar geoengineering-related scientific phenomena or principles, or claiming trivially modified natural materials. Caution within patent offices (as well as clearer legal doctrines, including more clearly prohibiting patenting of such putative "inventions") would reduce the likelihood of such problematic early, broad, and excessive patents. An international patent and trade secrecy monitoring panel could make recommendations to governmental agencies and legislatures if patenting activity or trade secrecy appeared to pose a threat to the responsible research and development of solar geoengineering technologies. The panel could also coordinate efforts to collect and make available relevant prior art in order to aid national patent offices in examining solar geoengineering patent applications, so as to restrict granted claims to truly novel and nonobvious inventions. Engaging the broader solar geoengineering research community in documenting their tacit and codified knowledge for ready use by patent offices might also be useful. The panel could be comprised of members of relevant national and regional patent offices, supplemented by academic and industry experts drawn from both within and beyond the research community.

The fourth and final proposal is for governments to clarify the conditions under which they would: exercise march-in rights; use governmental authority to use patented solar geoengineering technologies or solar geoengineering-related trade secrets without charge (if government funded) or to provide reasonable compensation (if privately funded); or compulsorily license private or governmental access and use of solar geoengineering-related data, technologies and know-how at reasonable prices. The ex-ante reduction of uncertainty should help to facilitate development of a market, should research prove fruitful and should governments choose to move forward with solar geoengineering technology research, development, and possible implementation.

6 | CONCLUSION

As noted previously, there is an opportunity that might soon be lost to create a solar geoengineering research commons. We hope this call encourages prompt discussions of whether and how to adopt such measures or other alternative policy approaches. This is important because IP policy will shape public and private actors' incentives and the governance of solar geoengineering.

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CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

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