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A Public Good? Geoengineering and Intellectual Property

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Nathan Hedberg graduated from the University of California, Berkeley with Bachelors degrees in molecular biology and architecture, minoring in civil/environmental engineering and urban/regional planning. Following this he took a short break from academia to work for the City of Berkeley integrating health policy and land use planning for a new downtown area plan, and conducting postmarket pharmaceutical clinical research for Westat out of California Pacific Medical Center in San Francisco. He is currently pursuing an MPH in health policy and management from the University of Michigan School of Public Health, and is concurrently enrolled in the graduate certificate program in Science, Technology and Public Policy at the Ford School of Public Policy. His primary interests lie in the intersection of innovation, business, and public policy, particularly in biomedical research. In the long-term, he is seeking to integrate both public and private sector work in the development of efficient, equitable policies for research and development in the biotech sector, and hopes to pursue a doctorate in neuroscience as time allows.

Molly Maguire graduated from St Andrews University in 2006, where she studied Modern History. Her focus was primarily on the American history of science, and completed her thesis on the 1925 Scopes "Monkey" Trial. In particular, her thesis chronicled the religion vs. science paradigm that crystallized at the trial and its modern implications. As a graduate student at University of Michigan's Ford School of Public Policy and a candidate in the Science, Technology and Public Policy program, Molly has worked on bioethics issues, including informed consent, governance in stem cell technology, access to IVF, and the place of the public interest in American patent policy. She plans to pursue a PhD in this area following completion of her Masters in 2011.

Jessie Mannisto is a Masters student at University of Michigan's School of Information specializing in information policy. Her research interests include intellectual property, accessibility to scholarly and government information, the changing roles of libraries, and related technology policy. In the future, she hopes to work for the Library of Congress Congressional Research Service or a similar institution. As an undergraduate, she studied English/Writing and Japanese at Kalamazoo College. In 2005, she worked as a US Pavilion Guide at the 2005 World Exposition in Nagoya, Japan.

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EXECUTIVE SUMMARY

Intellectual property (IP) is often unrecognized as a form of governance, but it shapes the development of technology in pivotal ways. Both the US and UK governments have recognized this in their discussions about the governance of geoengineering, suggesting that perhaps this new high-risk, high-reward technology should be "regulated as a public good" (United Kingdom, 2010; Royal Society 2010). Our preliminary research assesses the current geoengineering patent landscape in the United States and demonstrates that, while relatively few patents have been granted to date, certain trends – including the provision of broad patent language, dramatically increasing numbers of applications, and the concentration of patent ownership – suggest that patents will play an important role in how this technology develops. These developments are particularly troubling because of the high risks and uncertainties of geoengineering, and because of their resemblance to the biotechnology patent landscape in the US, which has been increasingly attacked because it may be stifling innovation and working against the public interest.

This memo explores the possibility of creating a *sui generis*[1] system for geoengineering patents, and investigates the current approach to atomic energy patents in the United States as a potential model. If we act now, we have a window of opportunity to avoid the problems that arose in biotechnology and establish a patent system that will guide geoengineering technology toward the best interests of innovators and the public at large.

[1] *Sui generis* – unique, constituting a class alone. (Mirriam Webster, 2010)

Geoengineering: A Public Good?

Because the United States and United Kingdom governments have many concerns about who will control geoengineering technologies—interventions designed to counteract climate change on a global scale—they have sponsored examinations of the available governance options (United States & United Kingdom Joint Statement, 2010). In its 2010 report, *The Regulation of Geoengineering,* the UK House of Commons Select Committee on Science and Technology suggested that "geoengineering should be regulated as a public good" (Ibid., 29), referring to the power of intellectual property to shape the use of this new technology and the perils of private ownership in this high-risk, high-reward situation. However, the report also recognized that without a robust patent regime, investment in and development of geoengineering techniques may be minimal (United Kingdom 2010).

Analyzing the Geoengineering Patent Landscape

A preliminary investigation[2] of the geoengineering patent landscape reveals the following findings: 1) different levels of activity between different types of geoengineering; 2) a recent rapid increase in patent applications covering geoengineering technologies; 3) broad patent language, likely covering many future innovations; 4) concentration of patent ownership among a few entities; 5) patents owned by non-practicing entities (NPE's); and 6) geoengineering patents issued by multiple patent offices to inventors across the world.

Different Levels of Patents Among Different Types of Geoengineering

The US Patent and Trademark Office (PTO) has issued many more patents on carbon capture at source and direct sequestration than more experimental techniques (such as sulfate aerosols or orbital mirrors, referred to here as 'exotic' techniques) collectively. We found approximately 160 patents and an additional 130 applications related to CCS and direct sequestration, many involving both technologies in a combined process, in comparison to only 21 patents and 52 applications for all other methods. This finding makes sense in the context of the state of the industry; CCS and direct sequestration have become an established practice in industry and power generation (treated as a form of industrial waste disposal) (Holloway 2001; Herzog 2001), while the 'exotic' techniques remain in early stages of experimental development.

[2] We are currently continuing our research. We restricted ourselves to a very limited definition of 'geoengineering patents' to keep our estimates conservative and restrain the initial scope of the project. This resulted in a representative, but not complete, survey. Broadening this definition not only has the potential to dramatically increase the number of applicable patents and applications, but as well raises important questions concerning the definition of the scope of technologies relevant to geoengineering.

The study consisted of manual search queries of the United States Patent Office (USPTO) granted patent and patent application databases as well as the European Patent Office (EPO) 'espacenet' worldwide patent databases. We conducted an initial literature review of geoengineering research to establish our search terms. While we reviewed patents granted outside the US for context and comparison, we focused primarily on the US.

After the searches were completed, we compiled and analyzed the results quantitatively (patent/application numbers, time trends, etc) and qualitatively (patent owners, scope of claims, concreteness of premise, etc). Please note that any specific patent references listed are for demonstrative purposes only; it is not our intention to single out particular inventors or inventions but rather to give the reader an idea of what we have been examining.

Of the 'exotic' techniques, the majority of the patents covered 'air scrubbing' (direct removal of CO_2 from ambient air) (~25), ocean fertilization (~15), or aerosol-based albedo enhancement techniques (~10). We found a broad representation of 'other' patents, however, including virtually every category mentioned in the UK House of Commons report discussed above (United Kingdom 2010) as well as some novel techniques.

A Recent Rise in Patent Applications

Although only 2 patent applications related to 'exotic' geoengineering methods or technologies were submitted in the 24 month period 2001-2002, this number has increased annually, with 31 applications filed (a 1500% increase) so far for 2009-2010 (as of 5/5/2010, not including the full 2010 calendar year). This increase in patent applications is consistent with the recent growth of scientific and commercial interest in the topic (Inman 2009 7-9). Thus, while the current number of patents in this area is relatively small, this may not be the case for very long. The longer policymakers delay a *sui generis* patent scheme, the more retroactive modifications of patents may be needed. This will increase the difficulty of implementing any prospective system.

Broad Patent Language

PTO is currently granting geoengineering patents with broad language, potentially hindering future innovation, allowing early innovators to control the use of geoengineering technologies, and paving the road to costly legal disputes down the line (Merges et al, 1990). As an example, we offer the claims of one active patent on ocean fertilization, which begins with:

> 1. A method of sequestering carbon dioxide in a deep open ocean comprising the following steps:
>
> (1) testing an area of the surface of a deep open ocean, in order to confirm that at least a first nutrient is missing to a significant extent from said area, and to indentify said first missing nutrient, and
> (2) applying to said area a first fertilizer which comprises said first missing nutrient, to fertilize said area with an appropriate amount of said first missing nutrient whereby carbon dioxide is sequestered,
> (3) limiting zooplankton and fish growth in said area by applying said first fertilizer in pulses; and
> (4) measuring the amount of sequestered carbon dioxide that results from said fertilization of said area (Markels 2000).

This first claim, and the patent's subsequent claims, could apply to any number of approaches to ocean fertilization. Furthermore, this patent, like many others we found, covers 'methods', rather than 'products' (covering a specific apparatus), and included very generous definitions of applicability. Taken together, these facts make patents more difficult to innovate around and increase the probability that these patent holders will control whether and how these technologies are used, contrary to any notion of a 'public good' (Merges et al, 1990; USFTC 2003). This is particularly important because of both the early stage of these technologies and the enormous risks and uncertainties associated with deployment of geoengineering technology by an individual patent holder.[3]

[3] On a related note, some of the patents reviewed that did not explicitly relate to geoengineering (and were not

Finally, PTO has granted patents of questionable feasibility or difficult implementation, further signaling a limited amount of filtering by the USPTO in reviewing these patents. If we seek to regulate geoengineering as a public good, putting into private hands patents such as 5,762,298, "Use of artificial satellites in earth orbits adaptively to modify the effect that solar radiation would otherwise have on earth's weather," (Chen 1998) could seriously impede action on technologies or techniques that only governments can or should feasibly execute in any event.

Concentrated Ownership and Non-practicing Entities

Compounding the problems of broad patent language are the issues of distribution of ownership and control. Though our sample size is small, we do see early trends towards concentrated patent ownership. Non-practicing entities (see below) and commercial ventures, in particular, have filed applications for a number of variants on one technology, often resulting in one or a handful of innovators controlling a significant proportion of the patents in a particular method of geoengineering. For example, one applicant holds 8 of the patents on ocean fertilization (out of the 15 patents and applications found in this area), and another has applied for 5 (of 10) in sulfate aerosols and 4 (all) in ocean strata modification. While this may just be a result of the small number of applications to date, it could allow a relatively small number of owners to control innovation in a particular area of geoengineering. Just as with our finding of broad patent language, this emerging situation creates a potential problem of control of these technologies among a relatively small number of private entities. Unlike more careful screening of broad language, however, numerous patents taken out by single individuals or groups are more difficult to control as all of the patents may very well be valid and we cannot force others to take out patents or arbitrarily deny them to inventors merely because no-one else is in the field.

We are also concerned about the involvement of non-practicing entities (NPE's), because of the unique role they play in innovation (Merges, et al., 1990; Chan, et al., 2009). While the implications of NPEs are not always clear, they can significantly influence innovation in particular sectors and exacerbate the problems we have raised previously, particularly with regards to the potential for extensive infringement litigation (USFTC 2003).

Geoengineering Innovation is International

Finally, while many patent applicants are from the United States, we also recorded inventors from Japan, the European Union, South Korea, and elsewhere (Asai, 1994; Lee, 2009) Additionally, most applicants holding or applying for more than one patent applied for patents at more than one office (i.e., those that applied in the US also applied in Europe, Japan, etc.). The global nature of this sector may require a global, rather than national, governance system, or at least a set of supplementary international treaties to complement any national programs.

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included in our count above) were largely similar in execution, differing only in intent (such as ocean fertilization techniques used for increasing marine food output as opposed to for sequestration). This highlights the potential difficulty in capturing all relevant technologies for the purposes of regulation as a 'public good' and the potential overlap some geoengineering technologies may have with unrelated applications.

Biotechnology: A Cautionary Tale

The current biotechnology patent landscape provides a useful comparison for geoengineering, as it demonstrates how the patent system can shape the development of a scientific field and its social, ethical, political, and environmental implications. In the absence of any significant regulatory framework (Ferrara 2001), the patent system has become the de facto method of controlling technological development (Jasanoff 2005). While some argue that it has led to the growth of an industry (Shand 2001), many have also suggested that so many patents have been issued, with such broad language and to a small group of inventors, that it has stifled the innovation process (Heller & Eisenberg 1998; Caulfield, et al., 2006; Caulfield, et al., 2000). Furthermore, many argue that the biotechnology patent landscape goes against the public interest because it increases the costs of health care unreasonably, has irreversible environmental implications, goes against public opinion, and commodifies life forms that should be considered part of the public sphere (Shand 2001).

Patents on biotechnological inventions grew rapidly starting in the 1980s, in response to the *Diamond v. Chakrabarty* decision (Diamond v. Chakrabarty 1980), which allowed patents on life forms, and the Bayh-Dole Act (Bayh-Dole Act 1980), which allowed universities to hold patents on federally-funded research (Sampat, 2006; Sampat, et al., 2003). Over the course of the next 30 years, the number of patents in this field increased exponentially, jumping from a yearly rate of less than 500 in the 1980s to 4,500 per year in 2001. (National Research Council 2006.) This upward trend is particularly meaningful given how biotech companies attract investment. In the absence of marketable products, a company's value has come to be determined according to its patent portfolio. (Jasanoff 2005; Rajan 2003)

Stifling Innovation and Higher Health Care Costs

Patents on human disease genes, in particular, have attracted controversy from within the scientific and medical communities (Association for Molecular Pathology, 1999; American College of Medical Genetics, 1999; American Academy of Clinical Laboratory Physicians and Scientists, 1999; College of American Pathologists, 2009). If inventors license their gene patents at all, they are usually done exclusively and for a very high price. Professional medical and scientific societies argue that this environment interferes with treatment, decreases patient options, and results in less research, as other laboratories are hampered in their ability to validate or further the study of new and existing mutations. (National Research Council, 2006) Thus, not only are genetic tests more expensive for patients because of the limited availability, but the tests are often less accurate because a robust research environment has not developed. Perhaps the most famous case is Myriad Genetics' patents on the BRCA genes, linked to inherited susceptibility for breast and ovarian cancer. Myriad shut down all other testing providers in the United States, and much of the research in breast cancer genetics (Parthasarathy 2007). This meant that the technology was not as sophisticated as the company claimed, and that only the very wealthy could afford the test (ACLU v. Myriad complaint, 2009). Although a New York federal judge invalidated these patents in March 2010 in response to a lawsuit filed by scientists, physicians, and patient advocates, the Myriad case remains a cautionary tale of how a patent holder's control over a technology can have significant negative implications for the public good.

Environmental and Global Economic Implications

Many scholars argue that patents on genetically modified organisms (GMOs) have had a negative impact on the environment and the developing world (Aoki, 2008; Ferrara, 2001). These patents have allowed a small handful of inventors to control the global food crop, which has led to dangerous monocultures (Crouch, 2001). In addition, it has transformed the economic landscape of farmers in the developed and developing world. In the United States, small farmers have disappeared, while in the developing world, subsistence farmers increasingly depend upon the aid and seeds provided by the developed world (Shiva, 2001). In the absence of any significant regulatory framework to cover agricultural biotechnology in the United States, the patent system has shaped the future of agriculture in profound and irreversible ways (Steinbrecher, 2001).

Ethical Implications

Finally, many argue that patents should never have been allowed because they promote the commodification of life forms, which should remain in the public domain. Scholars and activists first articulated this charge in an amicus brief in the *Diamond v. Chakrabarty* case (People's Business Commission, 1980), and have continued to make this argument as higher-order living organisms (and parts of these organisms) have become patentable (Dowie, 2004; US House of Representatives, 1988). While these concerns have not changed US policy in this area—today, animals, plants, genes, stem cells, and methods of creating human beings are all patentable—they have inspired growing public discussion about and grassroots-led challenges to the limits of patentability and the meaning of the public interest in this context (American Anti-Vivisection Society et al., 2007; Newman, 1997; Zwerdling, 1997). The lawsuit against Myriad Genetics discussed above, in which the American Civil Liberties Union brought together patient advocates, scientists, and physicians as plaintiffs, provides one such example. Meanwhile, the European Patent Office has responded to these concerns by preventing patents on inventions that promote the commercialization or industrialization of human embryos (e.g., human embryonic stem cells) (European Parliament and Council, 1998). Geoengineering inventions also raise questions about the ethical limits of patentability. Should such inventions, which have the potential to mitigate the effects of climate change but also do a great deal of damage, be privately owned? To what extent will this be publicly acceptable? To what extent is the public acceptability of patents in this area important to consider?

Overall, the current geoengineering patent landscape looks very similar to the biotechnology patent landscape during its formative years. With little regulation in place during its development, patents became the *de facto* form of governance in the biotechnology sector. **If we continue to deal with geoengineering patents as we did in biotechnology, we could create problems that are similar—or perhaps even worse—because of the high-risk, high-reward nature of the technology. The patent holders will control whether and how geoengineering technology will be researched and used.**

Atomic Energy: Controlling Technological Development and Use through Patents

While biotechnology provides an example of how geoengineering could develop if the current patent system remains unchanged, atomic energy provides an example of how a *sui generis* patent system can be created to shape the development and use of a technology. In 1946, Congress established a set of rules for the patentability of technology related to nuclear weapons and energy.[4] It created these rules as part of the Atomic Energy Act in order to address concerns about the national security implications of atomic energy development while still promoting development of this industry (Atomic Energy Act, 1954). Indeed, though Congress chose not to exercise this power in the case of biotechnology, the Supreme Court invoked the Atomic Energy Act in the *Diamond v. Chakrabarty* ruling as evidence that Congress does have the power to set an area of development off-limits for patenting (Wellerstein, 2008). The Court interpreted the lack of a governance mechanism for biotechnology patents as an active choice by Congress, a precedent that could also be applied to geoengineering in the future if no legislative action is taken. The parallels between atomic energy and geoengineering are obvious: both are global in scope, controversial, and have significant national security implications. Perhaps most significantly from a regulatory standpoint, while policymakers want to encourage development in this field due to concern about the effects of climate change, they also must be concerned about who will control this technology, how it will be developed and used, and how to minimize the technology's risks while maximizing its benefits.

Benefits of a Sui Generis Patent System

A properly designed *sui generis* patent system has several benefits. First, it can respond to the special needs of a technological sector. Each field of technology has a different set of inherent risks; it is therefore unreasonable to expect a universal patent system to be able to properly respond to the public interest concerns raised by this high-risk sector. Second, it allows government to have greater control over a field that could have high value, but would otherwise be unacceptably risky. The current approach, demonstrated by the biotechnology comparison, which allows inventors with patents and financial strength to control development and use, tends to favor the short-term interests of investors (Parthasarathy, 2007). Like atomic energy, however, scientists speak of geoengineering as a public good: the government therefore has an interest in directing the development of this technology. Private corporations have do not always have compelling reasons to consider the social complications of geoengineering technologies, making governmental involvement in the development stages crucial. Further, regulation of a public good necessitates complex questions regarding who constitutes the public and which bodies are appropriate for oversight. Global public goods having international ramifications are more complex yet, as they must take into account cross-national and cross-cultural concerns.

Third, by focusing on a specific field, a *sui generis* system can take into account the complex effects of each patent. The Atomic Energy Commission (AEC), for example, considered much more than PTO's traditional criteria of novelty, inventive step, utility, and sufficient description (Riesenfeld, 1958). In addition to the normal patenting criteria, the AEC considered the location where the technology was invented, funding sources, and national security implications of the potential patent (Wellerstein, 2008). In this process, a controlling body such as the AEC can develop unique expertise in the field, thereby equipping its members to view the landscape of the technology as a whole and better judge its future trajectory.

[4] Such rules governing patentability from Congress are not unusual in the case of atomic energy. For example, no patents are allowed on human beings (Hynes, 2008). The International Union for the Protection of New Varieties of Plants (UPOV), an international union to which the U.S. is a member, sets definitions of patentability governing plants and plant breeders rights (Robinson, 2008).

Given the inherent risks in geoengineering, and considering the analogs of biotechnology and atomic energy, a *sui generis* patent system is the most appropriate method of governance to direct the field of geoengineering as a public good.

Atomic Energy vs. Geoengineering

Both geoengineering and atomic energy are high risk technologies with the potential for a high reward; their impacts, positive and negative, are global in scope and if either does damage, it is likely to be irreversible. In addition, Congress chose to impose limits on atomic patents due to the large amount of public funding that would be used to develop the technology, and the need for a single body—in this case, the newly-established AEC—to oversee the entire developmental landscape to guide innovation to develop the technology more quickly (Riesenfeld 1958). While the federal government has not yet committed major funds for geoengineering, this will likely change upon further deliberation, with the House Science and Technology Committee's call for consideration of potential research activities (Committee on Science and Technology, 2010), the National Science Foundation's stated intention to pursue geoengineering research (NSF, 2009), and the ongoing discussions of the National Commission on Energy Policy's Task Force on Geoengineering and Climate Change (Bipartisan Policy Center, 2010) If federally funded groups decide to proceed with geoengineering research, the research environment will look more and more like that of atomic energy, and the government will have to assess how it wants to treat the fruits of this research.

Moreover, geoengineering as a scientific field needs urgent attention and focused development, as the window of time during which these technologies can successfully be deployed may be brief. Private organizations such as Climos and the Silver Lining Project are therefore already going ahead with their own research, citing the need to immediately address climate change (Wood, 2009). A similar need for oversight to guide and accelerate development of atomic energy was a key justification for regulators during the Cold War as well (Wellerstein, 2008).

Designing the System

The Atomic Energy Acts created a three-tier system of non-patentable, government patentable, and privately patentable technologies. Congress limited non-patentable technology to inventions that were solely useful in "special nuclear material" (*i.e.* plutonium and uranium) or "atomic energy in an atomic weapon" (USPTO, 2008). The government owned the patents on technology developed through federal research; it also had a "reserve power" to require compulsory licenses on technologies in the public interest (Riesenfeld, 1958). PTO offered its regular patents on all other technologies—subject to its usual examination and granting process. Patent protection also depended on the extent to which an invention was useful in atomic weapons or energy: if an invention was useful in another field as well as in atomic technology, the inventor could receive patents on these other uses. The AEC's successor, the Department of Energy, continues to oversee this system today.

Though the atomic energy patent system provides a useful starting point, a geoengineering patent regime will require some modifications. First, while Congress was able to define non-patentable technology as fissionable material, geoengineering lacks any similar analog. It includes a wide range of technologies, from stratospheric sulfate aerosols to mirrors to be built in space. Moreover, these inventions are often useful for applications unrelated to geoengineering. For example, while one form of solar radiation management uses mirrors placed high in the atmosphere to achieve a cooling effect, US Patent 5,041,834 covers a similar type of mirror that deflects solar radiation as a military weapon (Koert, 1991). The precedent of patentability *to the extent that* an invention is useful in atomic energy is therefore highly applicable to and useful in case of geoengineering. A geoengineering patent system also needs to carefully consider and define which aspects of the field should be non-patentable. When considering questions of risk and scale, for example, one must consider that most technologies can be developed along increasingly risky paths or scaled up. A new patent system would need to apply similar care in distinguishing between government and private patents, as the Bayh-Dole Act limits the government's ability to hold the patents on technology developed with public funds in a way it did not in the heyday of atomic energy.

The atomic patent system also prevented patents from interfering with research in that critical field (Riesenfeld, 1958). Today's biotechnology field illustrates the limitations that the patent system imposes on research and innovation, but also shows the difficulty of distinguishing between research and implementation. For example, patents on genes prevent medical researchers from doing diagnostic tests as part of their research, because patent holders often define the research exemption rather narrowly (Parthasarathy, 2007). The distinction between testing the deployment of sulfate aerosols and "actually" testing sulfate aerosols would be no easier to make. The atomic patent system included a strict definition of research and development (42 USC 2014(x)). This would also be necessary in a geoengineering system, though the definition may not be the same.

Finally, atomic energy patents operated in the context of a national system. Geoengineering, however, only makes sense on a global scale. While the United States can only control its own patent policy, it may be able to set a standard for other nations to follow, as has been the case with other landmark decisions such as *Diamond vs. Chakrabarty*. The World Intellectual Property Organization (WIPO) provides one possible forum to address the inherently international questions raised by geoengineering technologies; the USPTO could also collaborate with its counterparts in the European Union and Japan to establish an international norm.

Recommendations

Recommendation 1:
Stop issuing broad patents.

Broad patents stifle innovation and concentrate ownership. Both of these conditions are dangerous for geoengineering development. Additionally, we recommend retroactively cancelling or narrowing previously awarded broad patents. Our research shows that ownership of geoengineering patents has already concentrated in the hands of a small number of businesses, and the biotechnology comparison demonstrates the problems associated with this approach. Even a small number of overly broad patents in a few hands could gravely and irrevocably affect the development of geoengineering. We recommend working with the PTO to ensure only narrow geoengineering patents are awarded in the future. Narrowing the scope of such patents is a crucial first step in developing a governance structure for geoengineering patents.

Recommendation 2:
Create an Interagency Geoengineering Patent Task Force.

An oversight body, the Interagency Geoengineering Patent Task Force, should be created to oversee the geoengineering patent space. Membership of the Task Force would include agencies with clear interests in geoengineering, including the EPA, DHS, DOD, DOE, HHS and PTO. Additionally, several representatives of the public should be on the Task Force panel to provide a lay perspective[5] (Beierle 2000; Wynne, 1996; Epstein, 1995; Jasanoff, 1997). The Task Force would have two functions. First, it would track the geoengineering patent landscape on an ongoing basis, mapping the environment as it develops. This kind of tracking and mapping is crucial for geoengineering patents, as it provides an important and often overlooked opportunity for anticipatory governance (Guston 2008; Guston & Sarewitz, 2002). Such oversight allows us to understand how the industry is developing, and to step in quickly if development is not in the public interest.[6] Second, it would review patent applications related to geoengineering, as described in Recommendation 3 below.

Recommendation 3:
Add geoengineering to the existing sensitive application warning system within the PTO and require patent review by the Interagency Geoengineering Patent Task Force.

Geoengineering patents should be red-flagged at the application stage. PTO art units are already trained to do this, through the Sensitive Application Warning System (SAWS) (Falcone, 2006), and could be easily trained to incorporate geoengineering into these assessments. However, the current system within the PTO is informal (Falcone, 2006). We suggest that geoengineering patent applications flagged through SAWS undergo additional review by the Task Force. After completing the standard assessment of the application, examiners would refer it to the Task Force, which would then consider the potential effects of the technology when deciding whether and how to grant a patent. In doing this, the Task Force would be equipped to make determinations about what the current geoengineering landscape looks like and judge how the new patent would change that landscape.

Recommendation 4: Offer non-patent based innovation incentives.

Innovation can be effectively encouraged without patents. The Ansari X Prize, awarded for the successful development of the first private spacecraft, has demonstrated that financial awards will stimulate invention (Kalil 2006). The X Prizes, now expanded to include genomic sequencing, environmentally friendly automobiles, rockets, robotics and deep ocean exploration, (Kalil 2006; Wright, 1983; Chari, et al., 2009; Hynek, 2008; Wei, 2007) have proven effective at encouraging innovation without the promise of patentability. A similar mechanism could be used for geoengineering. Overseen by the Task Force, such prizes could focus efforts in specific directions, such as toward specific carbon sequestration techniques, thus fulfilling the Task Force's role of helping to direct the path of geoengineering development. In addition, award of the prizes would get around concerns of intellectual property protections for geoengineering.

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[5] Public participation is an important part of the proposed Task Force. By involving the public directly in the governance, the Task Force gains a broader knowledge base as well as the credibility it will need to maintain democratic legitimacy in the face of increasing public intervention into this space (Beierle, et al. 2000, 588).

[6] Nanotechnology, another potentially high-risk, high-reward technology provides some insight into the benefit of developing anticipatory governance. The National Nanotechnology Initiative (NNI) has been funding societal research into the development of anticipatory governance. Several guiding principles of the initiative include that nanoscience "should be performed with an interdisciplinary bent, …be oriented toward improving the economic competitiveness of the United States… and it should be subject to suitable administrative oversight" (Guston, 2008, p. 940).

Conclusion

Particularly in loosely regulated areas of innovation, as the biotechnology comparison demonstrates, patents can become the *de facto* form of governance and control the future of a technological field. Because of the scope, potential risks and benefits, national security implications, public controversy, and need for coordination in geoengineering, it should be treated like atomic energy—a sui generis patent system is necessary. Our survey of the current geoengineering patent landscape demonstrates patents are broad, increasing in number, and concentrated in a small number of owners. Without some sort of *sui generis* patent system, it will be very difficult to control development and use of these technologies through traditional regulatory efforts alone.

The risks of geoengineering are no less than those of atomic energy. Geoengineering stands to have a global effect with irreversible consequences. Experimentation and implementation of geoengineering technologies are extremely difficult to differentiate, further complicating the issue. Government must therefore be able to reach in and take ownership of certain patents deemed too risky be to left in private hands. Given the incredibly high stakes of geoengineering and climate change, a body with responsibility to the public—and with a broad, interdisciplinary, perspective—must use the power of the patent system to ensure the public good. If geoengineering is a ship, patents are the rudder, providing a mechanism to direct its path, maximizing its potential benefits while minimizing its potential risks. However, the narrow window in which we have to act is rapidly closing. Geoengineering will continue to follow the path already tread by biotechnology, if no patent intervention occurs soon.

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