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Solar Climate Engineering and Intellectual Property: Toward a Research Commons

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Solar Climate Engineering and Intellectual Property: Toward a Research Commons

Jesse L. Reynolds,* Jorge L. Contreras† & Joshua D. Sarnoff‡

ABSTRACT

Climate change is one of the greatest challenges confronting society today. Solar climate engineering (SCE) has the potential to reduce climate risks substantially. This controversial technology would make the earth more reflective in order to counteract global warming. The science of SCE is still in its infancy, and SCE research and development should proceed in a coordinated, responsible, and expeditious fashion. However, the roles of patents, research data, and trade secrets in SCE research remain unclear and contested. To this end, this article identifies concerns that may arise from the acquisition of intellectual property rights in SCE and proposes the formation

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of an SCE “research commons” and “pledging” to facilitate responsible SCE research and development. This research commons would permit public and private sector research institutions around the globe to share their research data. They would also pledge to avoid trade secret protections and that any patents they obtain would be managed so as to reduce unnecessary barriers to research and development of safe and effective SCE technologies.

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INTRODUCTION

Climate change is arguably the greatest environmental challenge confronting global society. Yet nearly thirty years after significant concerns first arose, progress toward preventing it remains insufficient. Atmospheric concentrations of greenhouse gases (GHGs), the cause of climate change, continue to increase annually.¹ The concentration of carbon dioxide, the most important GHG, is presently roughly forty percent greater than its preindustrial value.² Even if one assumes that the nonbinding first round of pledges that

1. See U.N. ENV'T PROGRAMME, EMISSIONS GAP REPORT 2015 3 (2016), http://uneplive.unep.org/media/docs/theme/13/Emissions_Gap_Report_2016.pdf; see also Earth Sys. Research Lab., *Trends in Atmospheric Carbon Dioxide*, NOAA.GOV, <http://www.esrl.noaa.gov/gmd/ccgg/trends/> (last updated Dec. 5, 2016) (showing mean monthly CO₂ at Mauna Loa between 2012 and 2017).

2. Lisa V. Alexander et al., *Summary for Policymakers, in CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS: WORKING GROUP I CONTRIBUTION TO THE FIFTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE* 3, 11 (Thomas F. Stocker et al. eds., 2013) [collection hereinafter CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS] (“Carbon dioxide concentrations have increased by 40% since pre-industrial times . . .”).

countries adopted pursuant to the 2015 Paris climate change agreement are fully implemented, models indicate that global warming would go well beyond the limit that the Paris Agreement codified.³ Furthermore, even once emissions do peak and decline, elevated temperatures and atmospheric concentration of carbon dioxide will persist due to the gas's slow natural rate of removal and the ocean's thermal capacity.⁴

Scientists and economists expect that climate change will have severe negative effects on humans and on ecosystems.⁵ Temperatures will increase.⁶ Precipitation will change as well, mostly increasing.⁷ Extreme weather events will be more frequent and more intense.⁸ These changes will, among other things, impact agriculture and raise the risk of food insecurity.⁹ Sea levels will rise, threatening low-lying coastal areas.¹⁰ Ecosystems will change, and threatened species will go extinct.¹¹

In response, some scientists and others are considering increasingly drastic action to reduce climate change risks. For example, in the mid-2000s, measures for adapting societies and ecosystems to a changed climate became the second primary category of responses to be internationally endorsed and coordinated.¹² In more recent years, techniques to remove

3. INT'L ENERGY AGENCY, ENERGY AND CLIMATE CHANGE: WORLD ENERGY OUTLOOK SPECIAL BRIEFING FOR COP21, 4 (2015), https://www.iea.org/media/news/WEO2015_COP21Briefing.pdf (forecasting 2.7 degrees Celsius warming by 2100, which is above the 2 degree stated goal); *see also* Conference of the Parties, *Adoption of the Paris Agreement*, art. 2.1(a), U.N. Doc. FCCC/CP/2015/L.9/Rev.1, Annex (Nov. 30, 2015) [hereinafter Paris Agreement] (agreeing to hold warming below 2 degrees Celsius and to pursue efforts to keep it below 1.5 degrees).

4. *See* Matthew Collins et al., *Long-Term Climate Change: Projections, Commitments and Irreversibility*, in CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, *supra* note 2, at 1029, 1107 ("Eliminating CO₂ emissions only would lead to near constant temperature for many centuries.").

5. *See* Field et al., *Summary for Policymakers*, in INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, FIFTH ASSESSMENT REPORT 1, 11–24 (Christopher B. Field et al. eds., 2014).

6. Field et al., *supra* note 5, at 14.

7. *Id.* at 12, 18, 21, 23–24.

8. *Id.* at 12–13.

9. *Id.* at 17–18.

10. *Id.* at 12–13.

11. *Id.* at 14–15.

12. *See* E. Lisa F. Schipper, *Conceptual History of Adaptation in the UNFCCC Process*, 15 REV. EUR. CMTY. & INT'L ENVTL. L. 82, 89 (2006); *see also* Conference of the Parties, *Report of the Conference of the Parties on its*

carbon dioxide from the atmosphere as a means of mitigating climate risks are increasingly considered to be a necessary component of scenarios in which dangerous climate change would be avoided.¹³ These negative emissions technologies, such as directly capturing carbon dioxide from the air or accelerating natural weathering, are at various stages of research and development (R&D).¹⁴

An alternative—and controversial—approach to counteracting the warming effect of GHGs is to make the planet slightly more reflective or otherwise to block incoming sunlight.¹⁵ These “solar climate engineering” methods (SCE, elsewhere often “solar radiation management” (SRM), “solar geoengineering,” “climate geoengineering,” or “albedo modification”) presently appear to have the potential to reduce climate change significantly, yet pose physical and social risks of their own.¹⁶ Moreover, SCE would fail to address other adverse effects of GHG proliferation, such as ocean acidification.¹⁷

Sixteenth Session, Held in Cancun from 29 November to 10 December 2010. Addendum. Part II: Action taken by the Conference of the Parties at its Sixteenth Session, § II, U.N. Doc. FCCC/CP/2010/7/Add.1 (reporting that the U.N. party countries agreed to enhance adaptation, placing it on the same priority level as GHG emissions abatement).

13. See Detlef P. van Vuuren et al., *The Representative Concentration Pathways: An Overview*, 109 CLIMATIC CHANGE 5, 17–18, 21, 25 (2011) (modeling long term climate change and discussing carbon capture and storage as one of the technologies to be utilized in slowing climate change); Paris Agreement, *supra* note 3, art. 4.1 (agreeing to aim to limit climate change by establishing a “balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases”).

14. See NAT’L RESEARCH COUNCIL OF THE NAT’L ACADS. ET AL., CLIMATE INTERVENTION: CARBON DIOXIDE REMOVAL AND RELIABLE SEQUESTRATION ch. 3 (2015) [hereinafter CLIMATE INTERVENTION: CARBON DIOXIDE REMOVAL].

15. See generally NAT’L RESEARCH COUNCIL OF THE NAT’L ACADS. ET AL., CLIMATE INTERVENTION: REFLECTING SUNLIGHT TO COOL EARTH, 2, Box S.1 (2015) [hereinafter CLIMATE INTERVENTION: REFLECTING SUNLIGHT] (describing Albedo Modification: “intentional efforts to increase the amount of sunlight that is scattered or reflected back to space . . .”); OLIVER MORTON, THE PLANET REMADE: HOW GEOENGINEERING COULD CHANGE THE WORLD 54 (2015) (describing a “veil” around the earth as “[t]he most widely argued-over form of climate geoengineering . . .”).

16. Olivier Boucher et al., *Clouds and Aerosols, in CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS*, *supra* note 2, at 571, 575 (concluding that “[m]odels consistently suggest that SRM would generally reduce climate differences compared to a world with elevated greenhouse gas concentrations and no SRM . . .”). Note that SCE and negative emissions technologies are sometimes bundled together as “climate engineering” or “geoengineering.”

17. See CLIMATE INTERVENTION: REFLECTING SUNLIGHT, *supra* note 15, at 6.

One key reason that SCE-based proposals are highly contested is their uncertain physical and social risk profiles.¹⁸ These risks may be transboundary, and even global.¹⁹ Despite these risks, SCE is receiving increasing attention by scientists, policy makers, scholars, and others.²⁰ At the request of the United States Congress in 2012, the U.S. National Academy of Sciences in 2015 issued two reports on the current state of knowledge and the need for more research into both carbon dioxide removal and SCE.²¹ Further, the 2015 Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC) contemplates carbon dioxide removal, and its goal of maintaining temperatures well below a two degree Celsius increase over pre-industrial levels may be achievable only through the use of SCE.²²

Because some proposed SCE methods appear to have the potential to reduce climate change risks greatly, while at the same time creating countervailing risks, some form of SCE governance will be needed.²³ Indeed, the seminal report on

18. See John A. Dykema et al., *Stratospheric Controlled Perturbation Experiment: A Small-scale Experiment to Improve Understanding of the Risks of Solar Geoengineering*, 372 PHIL. TRANSACTIONS ROYAL SOC'Y A (Theme Issue No. 2031) 1, 1 (2014) ("In addition to the risks associated with current knowledge [of solar radiation management], the possibility of 'unknown unknowns' exists that could significantly alter the risk assessment relative to our current understanding.").

19. See Andy Jones et al., *The Impact of Abrupt Suspension of Solar Radiation Management (Termination Effect) in Experiment G2 of the Geoengineering Model Intercomparison Project (GeoMIP)*, 118 J. GEOPHYSICAL RES.: ATMOSPHERES 9743, 9743 (2013).

20. P. Oldham et al., *Mapping the Landscape of Climate Engineering*, 372 PHIL. TRANSACTIONS ROYAL SOC'Y A (Theme Issue No. 2031) 1, 5–6 (2014) (showing a rapid increase in the number of scientific publications on SCE since 2007).

21. CLIMATE INTERVENTION: CARBON DIOXIDE REMOVAL, *supra* note 14; CLIMATE INTERVENTION: REFLECTING SUNLIGHT, *supra* note 15.

22. Paris Agreement, *supra* note 3, art. 4.1 (agreeing to aim to limit climate change by establishing a "balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases"). See, e.g., JOSHUA B. HORTON ET AL., HARVARD PROJECT ON CLIMATE AGREEMENTS, IMPLICATIONS OF THE PARIS AGREEMENT FOR CARBON DIOXIDE REMOVAL AND SOLAR GEOENGINEERING 3–6 (2016), http://belfercenter.ksg.harvard.edu/files/160700_horton-keith-honegger_vp2.pdf; Olivier Boucher, et al., *In the Wake of Paris Agreement, Scientists Must Embrace New Directions for Climate Change Research*, 113 PROC. NAT'L ACAD. SCI. U.S. 7287, 7288 (July 5, 2016).

23. See, e.g., JOHN SHEPHERD ET AL., GEOENGINEERING THE CLIMATE: SCIENCE, GOVERNANCE AND UNCERTAINTY 41 (2009); CLIMATE INTERVENTION: REFLECTING SUNLIGHT, *supra* note 15, at 149–76 (calling for governance of SCE). See generally Daniel Bodansky, *The Who, What, and Wherefore of*

climate engineering from the United Kingdom Royal Society concluded that “[t]he greatest challenges to the successful deployment of geoengineering may be the social, ethical, legal and political issues associated with governance, rather than scientific and technical issues.”²⁴ However, developing governance structures will be a lengthy and difficult process, given international divisions over climate change, the absence of existing regulation, the low state of knowledge and concomitant high uncertainty, the lack of consensus among policy makers, the slowness of, and generally low appetite for, new global environmental agreements, and the threat of appropriation by rogue actors with subsequent destabilizing effects.²⁵ Although some normative principles have been developed by non-state actors (such as regulation of climate engineering as a public good; public participation; disclosure and open publication of research results; and independent assessment of impacts),²⁶ these are of uncertain effectiveness, in part because of their voluntary nature and because of their generality.²⁷ National governments or international bodies will need to help further these norms and other regulatory objectives.

Independent of future international law, national law, or non-state governance mechanisms, the policies regarding patents, trade secrets, and research data will play important roles in the governance of these technologies. In fact, intellectual property (IP)²⁸ policies often act as *de facto*

Geoengineering Governance, 121 CLIMATIC CHANGE 539, 542–43 (2013) (discussing general rules of international climate governance). On environmental governance generally, see Brian C. Chafin, et al., *Transformative Environmental Governance*, 41 ANN. REV. ENVTL. RESOURCES 399 (2016).

24. SHEPHERD ET AL., *supra* note 23, at xi.

25. See Joshua B. Horton & Jesse L. Reynolds, *The International Politics of Climate Engineering: A Review and Prospectus for International Relations*, 18 INT’L STUD. REV. 438, 443–45 (2016) (reviewing the arguments for and against the potential hostile and rogue use of SCE).

26. Steve Rayner et al., *The Oxford Principles*, 121 CLIMATIC CHANGE 499, 502–03 (2013).

27. See, e.g., *id.* at 503, 508 (proposing a number of broad “[p]rinciples . . . as a draft framework to guide the collaborative development of geoengineering governance” so as to create a “culture of responsibility,” and recognizing the potential inadequacy of voluntary regulation).

28. In this article, “intellectual property”/“IP” refers principally to patents, trade secrets, and research data. Other forms of IP, such as copyrights and trademarks, are less relevant to the issues discussed in this article.

governance mechanisms for emerging technologies in the absence of technology-specific law.²⁹ They do so through private and public decisions regarding control, development, and licensing of the technologies, and through normal state actions in regulating research, development, and implementation activities.

Relying on general market and regulatory processes to address SCE research, development, and possible implementation poses particular concerns due to the public good aspects of the technology and the potential for transboundary harm that the technology may create.³⁰ Indeed, some scholars have called for limitations on SCE patents. For example, an influential set of guiding principles for climate engineering argued that there should be a presumption against exclusive private control of SCE technologies and a need for specialized regulation of any IP:

Without precluding a role for the private sector, or the granting of patents, it is the case that the distribution of intellectual property rights can result in, or exacerbate existing, injustices. There should therefore be a presumption against exclusive control of geoengineering technology by private individuals or corporations. This does not mean that there can be no intellectual property in geoengineering, but that there might be a need for restrictions to ensure fair access to the benefits of geoengineering research.³¹

Thus, SCE may present challenges to traditional means of managing patented technologies and other IP. For example, the holders of essential SCE patents might demand high royalties for licenses for technologies that may be able to greatly reduce climate change risks, triggering controversial governmental responses to reduce prices.³² Further, some policy makers or other influential voices could assert that patents on means of intentionally altering the planet's climate are contrary to public morality and should not be permitted. Policies will need

29. See Oldham et al., *supra* note 20, at 1 (noting that “[I]n the absence of a governance framework for climate engineering technologies . . . the practices of scientific research and intellectual property acquisition can de facto shape the development of the field.”).

30. See, e.g., Rayner et al., *supra* note 26, at 505.

31. *Id.*

32. Cf. Natalie J. Tanner, *Understanding the Disparity in Availability of Prescription Drugs in the United States: Compromise May Be the Answer*, 2 IND. HEALTH L. REV. 267, 273 (2005) (“[G]overnments of industrialized nations, excluding the United States, impose price controls in order to keep the prices of pharmaceuticals low [T]he United States remains one of the only industrialized nations whose government has not imposed restrictions on pharmaceutical pricing.”) (internal quotations omitted).

to address issues common to emerging technologies, such as the risk that broad, early patents will hinder subsequent innovation.³³ On the other hand, the legal and non-legal governance of SCE IP may offer opportunities not only to address these and other challenges, but also to encourage the R&D of SCE in a manner that is safe, responsible, and congruent with the public interest.³⁴ These opportunities currently exist as a result of the early stage of SCE research, and the relative absence to date of extensive private sector engagement.³⁵

This article examines how the research, development, and possible implementation of SCE would challenge existing IP policies, and explores opportunities for innovative approaches to SCE IP governance in order to help ensure that SCE R&D proceeds appropriately. Our approach generally assumes that SCE is worth additional research and consideration, and that if it appears sufficiently safe and effective, it should be developed responsibly. We acknowledge the real concerns and risks, both environmental and social, but feel on balance that these can and should be managed through appropriate SCE research, governance, and monitoring, rather than the suppression of SCE research activities.

Part I of this article introduces SCE, its potential, and its risks. Part II describes the current regulation of, and market for, SCE and considers possible future scenarios of these. In Part III, we briefly review the existing landscape of SCE patents and their ownership, and current patterns of the development and coordination of research data and of possible trade secrets. Part IV explores potential challenges to SCE governance arising from IP rights and restrictions on research data, based on similar concerns that have arisen in other emerging fields. Part V considers a range of approaches, both public and private, to managing IP that policymakers have deployed in other fields. Part VI proposes the formation of a “research commons” and “pledge” approach, through which public and private actors could manage SCE patents and other IP rights and data in a manner that furthers SCE’s potential to reduce climate risks while minimizing its physical and social risks.

33. See discussion *infra* Section IV.E.

34. See discussion *infra* Section II.B.

35. See discussion *infra* Section II.B.

I. SOLAR CLIMATE ENGINEERING

As described above, SCE would make the planet more reflective or block incoming sunlight in order to counteract the warming effect of GHGs.³⁶ Only a small effect is needed: offsetting the warming that would arise from a doubling of the preindustrial atmospheric carbon dioxide concentration—which will probably be reached around the middle of this century—would require an approximately 1.8% reduction in incoming solar radiation.³⁷ Generally speaking, SCE could counter most climatic effects of elevated GHG concentrations (albeit imperfectly), would take effect rapidly, would have low direct financial implementation costs, would have global impacts, and would be reversible in its direct climatic effects.³⁸

Researchers have proposed several SCE methods, which vary in their expected capacities, feasibilities, costs, and risks.³⁹ Four techniques are discussed here. First, very fine particles, such as sulfate aerosols, could be injected into the stratosphere, a layer of the upper atmosphere.⁴⁰ These particles would deflect some incoming solar radiation and consequently cool the planet.⁴¹ There is a natural precedent: large volcanic eruptions have introduced sulfate aerosols into the atmosphere and have cooled the earth for a year or so.⁴² Of all the proposed SCE methods, stratospheric aerosol injection receives the most attention due to its expected low direct implementation costs, large cooling capacity, reversibility, and apparent technical feasibility.⁴³ This approach also may carry less uncertainty and be more acceptable to the public given the evidence from natural volcanic activity.

36. See CLIMATE INTERVENTION: REFLECTING SUNLIGHT, *supra* note 15 at 29–46.

37. SHEPHERD ET AL., *supra* note 23, at 23.

38. See *generally id.* at 23–36 (discussing the effectiveness, affordability, timeliness, and safety of different SCE methods).

39. See *id.*

40. See Sirisha Kalidindi et al., *Modeling of Solar Radiation Management: A Comparison of Simulations Using Reduced Solar Constant and Stratospheric Sulphate Aerosols*, 44 CLIMATE DYNAMICS 2909, 2910 (2015) (discussing this method).

41. *Id.*

42. See *generally* Alan Robock, *Volcanic Eruptions and Climate*, 38 REVS. GEOPHYSICS 191, 191 (2000) (describing many effects of volcanic eruptions on climate, including cooling phenomena).

43. See SHEPHERD ET AL., *supra* note 23, at 31 tbl.3.4.

Second, seawater could be sprayed as a fine mist into the lower atmosphere.⁴⁴ The salt particles that would remain airborne after the seawater's evaporation would serve as cloud condensation nuclei.⁴⁵ In turn, this would cause marine clouds to consist of smaller water droplets and be brighter.⁴⁶ Marine cloud brightening has received a significant but secondary degree of attention, perhaps because of its less environmentally intrusive means of intervention, its reversibility, and its potential for partial localizing of its effects.⁴⁷ Third, objects such as mirrors or dust could be placed in space, either in the earth's orbit or at a key point between the sun and earth.⁴⁸ Although the popular press often discusses space-based SCE, it is presently prohibitively expensive.⁴⁹ Finally, terrestrial surfaces could be made more reflective such as through genetically modified crops or brighter human-made structures.⁵⁰ This land-based SCE would have very limited cooling capacity and likely would be expensive.⁵¹ However, local benefits could be significant.

SCE is presently at an early stage of development. Total global SCE research funding is on the order of only ten million U.S. dollars per year.⁵² Almost all evidence thus far is from modeling work undertaken during the last fifteen years, and especially since 2008.⁵³ Scientists can draw some insights from existing analogs such as volcanoes, marine ships' cloud tracks, and lower atmospheric pollution, each of which reflect some

44. See, e.g., John Latham et al., *Marine Cloud Brightening: Regional Applications*, 372 PHIL. TRANSACTIONS ROYAL SOC'Y A (Theme Issue No. 2031) 1, 1–2 (2014).

45. *Id.*

46. *Id.*

47. See SHEPHERD ET AL., *supra* note 23, at 28 tbl.3.3.

48. See, e.g., Joan-Pau Sánchez & Colin R. McInnes, *Optimal Sunshade Configurations for Space-Based Geoengineering near the Sun-Earth L1 Point*, PLOS ONE, AUG. 26, 2015, at 1, 22.

49. See, e.g., SHEPHERD ET AL., *supra* note 23, at 33 tbl.3.5.

50. See, e.g., Hashem Akbari et al., *The Long-term Effect of Increasing the Albedo of Urban Areas*, ENVTL. RES. LETTERS, Apr. 12, 2002, at 1, 2; Bradley M. Zamft & Robert J. Conrado, *Engineering Plants to Reflect Light: Strategies for Engineering Water-Efficient Plants to Adapt to a Changing Climate*, 13 PLANT BIOTECHNOLOGY J. 867, 872 (2015).

51. See, SHEPHERD ET AL., *supra* note 23, at 25 tbl.3.1.

52. See *Geoengineering Research*, OPEN PHILANTHROPY PROJECT (July 2013), http://www.openphilanthropy.org/research/cause-reports/geoengineering#Who_else_is_working_on_this.

53. *Cf. id.* (citing no sources before 2008).

incoming solar radiation.⁵⁴ Researchers in the United Kingdom planned a field test of equipment for stratospheric aerosol injection in 2012, but they cancelled it due in part to concerns regarding a potential conflict of interest with a reviewer who had applied for a relevant patent.⁵⁵ The first outdoor experiments of the environmental impacts of SCE—in this case, those on stratospheric ozone from sulfate aerosols—are presently at the planning stage.⁵⁶ Some scientists envision a wider portfolio of SCE field trials.⁵⁷

Although SCE could reduce climate change and its risks at a gross level, it would also pose environmental and social risks, many of which would arise at the research stage. The primary physical risk of SCE arises from the fact that GHGs and SCE would influence the earth's climate in manners that are not perfect mirror images of each other.⁵⁸ The former traps heat globally, whereas the latter would have the greatest compensatory effect where sunlight is most direct: close to the equator.⁵⁹ Furthermore, because temperature differences are a leading driver of the planet's hydrologic cycle,⁶⁰ precipitation patterns would change both under climate change and under climate change plus SCE. Therefore, regional temperature and especially precipitation anomalies would persist with SCE. Nevertheless, models presently indicate that an optimized level

54. See, e.g., Y.-C. Chen et al., *Occurrence of Lower Cloud Albedo in Ship Tracks*, 12 *ATMOSPHERIC CHEMISTRY & PHYSICS* 8223, 8232 (2012) (employing ship track observations as means to assess the microphysics of aerosol-cloud relationships); Zhihong Zhuo et al., *Proxy Evidence for China's Monsoon Precipitation Response to Volcanic Aerosols over the Past Seven Centuries*, 119 *J. GEOPHYSICAL RES.: ATMOSPHERES* 6638, 6638 (2014) (explaining how the cooling effect of volcanic eruptions may play a role in weather conditions).

55. See Daniel Cressey, *Geoengineering Experiment Cancelled amid Patent Row*, *NATURE* (May 15, 2012), <http://www.nature.com/news/geoengineering-experiment-cancelled-amid-patent-row-1.10645>.

56. See Dykema et al., *supra* note 18.

57. See David W. Keith et al., *Field Experiments on Solar Geoengineering: Report of a Workshop Exploring a Representative Research Portfolio*, 372 *PHIL. TRANSACTIONS ROYAL SOC'Y A* (Theme Issue No. 2031) 1, 3 tbl.1 (2014) (charting the different tests and experiments available for Solar Radiation Management).

58. See *CLIMATE INTERVENTION: REFLECTING SUNLIGHT*, *supra* note 15, at 29–46.

59. *Id.* at 130.

60. See generally Nat'l Weather Serv., *The Hydrologic Cycle*, NOAA.GOV, <http://www.srh.noaa.gov/jetstream/atmos/hydro.html> (last visited Oct. 29, 2016) (showing how temperature differences condenses and vaporizes water throughout the hydrologic cycle).

of SCE could compensate for the vast majority of climate change's temperature effects and the majority of its precipitation effects.⁶¹

Besides precipitation, SCE would present other physical risks. Space-based SCE and stratospheric aerosol injection would globally reduce incoming sunlight, and the latter would make it more diffuse.⁶² This would affect agriculture and ecosystems. The leading candidate material for stratospheric aerosol injection—sulfate aerosols—is believed to catalyze the destruction of stratospheric ozone, which blocks harmful incoming ultraviolet radiation.⁶³ Negative environmental effects may not merely be physical, but also may manifest *inter alia* as impacts on humans, changes in food security, and the loss of biodiversity.⁶⁴

Other risks are social in nature. For example, the mere prospect of SCE may reduce the already insufficient and politically fragile efforts toward GHG emissions abatement.⁶⁵ If this were the case, then ocean acidification would worsen. Also, if SCE were to be implemented at a high intensity under conditions of elevated atmospheric GHG concentrations and were subsequently to stop—for whatever reason—then the climate change that had theretofore been suppressed would rapidly manifest, posing very large risks.⁶⁶ Another troubling

61. See Ben Kravitz et al., *A Multi-Model Assessment of Regional Climate Disparities Caused by Solar Geoengineering*, ENVTL. RES. LETTERS, July 22, 2014, at 1, 6–7. The precise degrees of compensation will depend on *inter alia* the relative values placed on different regions of the planet and on preserving temperature versus precipitation.

62. See J. Pongratz et al., *Crop Yields in a Geoengineered Climate*, 2 NAT. CLIMATE CHANGE 101, 103 (2012).

63. Giovanni Pitari et al., *Stratospheric Ozone Response to Sulfate Geoengineering: Results from the Geoengineering Model Intercomparison Project (GeoMIP)*, 119 J. GEOPHYSICAL RES.: ATMOSPHERES 2629, 2630 (2014).

64. See generally PHILLIP WILLIAMSON & RALPH BODLE, SECRETARIAT OF THE CONVENTION ON BIOLOGICAL DIVERSITY, TECH. SER. NO. 84, UPDATE ON CLIMATE GEOENGINEERING IN RELATION TO THE CONVENTION ON BIOLOGICAL DIVERSITY: POTENTIAL IMPACTS AND REGULATORY FRAMEWORK (2016).

65. See Jesse Reynolds, *A Critical Examination of the Climate Engineering Moral Hazard and Risk Compensation Concern*, 2 ANTHROPOCENE REV. 174, 175 (2015) (“Climate engineering proposals have been controversial for a variety of reasons. Perhaps the most widespread concern is that they would undermine mitigation efforts.”).

66. See Jones et al., *supra* note 19. But see Jesse L. Reynolds, Andy Parker & Peter Irvine, *Five Solar Geoengineering Tropes that Have Outstayed Their Welcome*, EARTH'S FUTURE (accepted for publication 2016, forthcoming), <http://onlinelibrary.wiley.com/doi/10.1002/2016EF000416/full> (last visited Jan. 2, 2017).

scenario is one in which SCE is implemented with a weak knowledge base, perhaps in response to perceptions of sudden and dangerous climate change.⁶⁷ Furthermore, any SCE activities undertaken at a substantial scale in one country would have transboundary effects.⁶⁸ To the extent that political leaders disagree regarding whether, when, and how to implement SCE, it could exacerbate international tensions.⁶⁹ Countries that experienced extreme weather events or other damaging environmental anomalies could blame the states or other actors that implemented or tested SCE. Some may even suspect, rightly or wrongly, that those engaged in SCE did so in order to gain an economic or military advantage.⁷⁰ Finally, stratospheric aerosol injection and perhaps marine cloud brightening appear to be inexpensive and feasible enough that small states or even wealthy nonstate actors could implement them, with global impacts.⁷¹ Political scientist David Victor wrote, alluding to the villain from a James Bond film, that “[a] lone Greenfinger, self-appointed protector of the planet and working with a small fraction of the [Bill] Gates bank account, could force a lot of [solar] geoengineering on his own.”⁷² As described in the following Part, SCE regulation is insufficient, both nationally and internationally to address these concerns. Some of these concerns relate to IP and are discussed in Part IV.

67. See Joshua B. Horton, *The Emergency Framing of Solar Geoengineering: Time for a Different Approach 2* ANTHROPOCENE REV. 147, 149 (2015).

68. See CLIMATE INTERVENTION: REFLECTING SUNLIGHT, *supra* note 15, at 29–46.

69. See Horton & Reynolds, *supra* note 25 (reviewing arguments and evidence concerning international tensions, blame, and problematic unilateral action).

70. See *id.*

71. See SHEPHERD ET AL., *supra* note 23, at 31 tbl.3.4; SHEPHERD ET AL., *supra* note 23, at 28 tbl.3.3. At the same time, the capacity for unilateral or unilateral action may also be an advantage, in which SCE is able to break through the political stalemate and collective action problem of GHG emissions abatement. See John Virgoe, *International Governance of a Possible Geoengineering Intervention to Combat Climate Change*, 95 CLIMATIC CHANGE 103, 116 (2009).

72. David G. Victor, *On the Regulation of Geoengineering*, 24 OXFORD REV. ECON. POL'Y 322, 324 (2008); see GOLDFINGER (Eon Productions 1964). Consider the unauthorized ocean fertilization experiment of 2012. Jeff Tollefson, *Ocean-Fertilization Project off Canada Sparks Furore*, 490 NATURE 458 (2012). *But see* Horton & Reynolds, *supra* note 25.

II. SOLAR CLIMATE ENGINEERING REGULATION AND MARKETS

A. SOLAR CLIMATE ENGINEERING REGULATION

Although SCE presents both possible benefits and risks, there is a widely acknowledged governance gap.⁷³ In fact, there is no regulation that is specific to SCE, legally binding, and in effect.⁷⁴ Instead, a patchwork of existing regulatory mechanisms may potentially apply to SCE activities.⁷⁵ Which ones would be applicable, and in what manner, would be contingent upon *inter alia* the nature of the SCE activity at hand, its scale, the state of knowledge at the time, where it is undertaken, by whom, with what intentions, and the willingness and ability of national regulators, intergovernmental organizations, and other entities to exert control over the activities.

For example, within the United States, reporting requirements under the Weather Modification Reporting Act of 1972 may apply to those engaged in SCE field activities.⁷⁶ The U.S. Environmental Protection Agency (EPA) potentially could interpret the definition of “pollutant” to include SCE emissions, which would trigger its authority to regulate SCE methods such as stratospheric aerosol injection.⁷⁷ Notably, the Clean Air Act allows the EPA some discretion in regulating research projects.⁷⁸ The National Environmental Policy Act (NEPA) might, under circumstances such as public funding of research

73. See Virgoe, *supra* note 71, at 109–12.

74. See Jesse Reynolds, *Climate Engineering and International Law*, in CLIMATE CHANGE LAW 178, 181–83 (Daniel A. Farber & Marjan Peeters eds., 2016).

75. See *id.*

76. See Weather Modification Reporting Act of 1972, Pub. L. No. 92-205, § 3(a), 85 Stat. 736 (1971) (enacted primarily to address the practice of cloud seeding); see also National Weather Modification Policy Act, 15 U.S.C. § 330 (1976); CLIMATE INTERVENTION: REFLECTING SUNLIGHT, *supra* note 15, at 169.

77. 42 U.S.C. §§ 7401–7661 (2012). For the definition of pollutant, see U.S.C. § 7602(g) (2012). See generally Tracy D. Hester, *Remaking the World to Save It: Applying U.S. Environmental Laws to Climate Engineering Projects*, 38 ECOLOGY L.Q. 851, 876 (2011) (“Given its willingness to regulate activities to reduce the effects of GHG emissions, EPA may take an expansive view of the Clean Air Act’s applicability to other activities that might alter climate processes or directly release aerosols or other compounds into the atmosphere to mitigate climate change effects.”).

78. 42 U.S.C. § 7403 (2012).

or large-scale outdoor SCE activities, require an environmental impact assessment or a programmatic environmental impact statement if the risks were thought to be significant.⁷⁹ Other possible existing regulatory pathways include the Clean Water Act and the Endangered Species Act, as well as state-level cloud seeding regulations.⁸⁰

Given SCE's widespread effects, existing international law and intergovernmental institutions also might regulate some SCE activities.⁸¹ The UNFCCC and its related protocols currently offer little guidance, as they focus on stabilizing GHG concentrations, but the UNFCCC institutions may be a natural locus for vesting increased international regulatory capacity over SCE.⁸²

The U.N. Convention on the Law of the Sea (UNCLOS) may currently offer the greatest applicability to all forms of SCE due to its numerous and general environmental provisions, its widespread participation, and the impacts of both climate change and SCE on the marine environment.⁸³

79. 42 U.S.C. § 4321–4370h (2012).

80. 33 U.S.C. §§ 1251–1387 (2012); 16 U.S.C. §§ 1531–1544 (2012); see Rachel Hauser, *Using Twentieth-Century U.S. Weather Modification Policy to Gain Insight into Global Climate Remediation Governance Issues*, 5 WEATHER, CLIMATE & SOC'Y 180, 190–91 (2013) (discussing North Dakota's oversight of weather modification).

81. See Catherine Redgwell, *Geoengineering the Climate: Technological Solutions to Mitigation-Failure or Continuing Carbon Addiction?*, 5 CARBON & CLIMATE L. REV. 178 (2011) (discussing the potential for various regulatory structures for SCE's including international and intergovernmental institutions, and arguing that international regulation is not the best method); Jesse Reynolds, *Climate Engineering Field Research: The Favorable Setting of International Environmental Law*, 5 WASH. & LEE J. ENERGY CLIMATE & ENV'T 417 (2014) (examining various international environmental law and proposing that this framework is favorable for climate engineering research and regulation).

82. United Nations Framework Convention on Climate Change, May 9, 1992, 1771 U.N.T.S. 171 [hereinafter UNFCCC]. Compare Matthias Honegger et al., *Tackling Climate Change: Where Can the Generic Framework Be Located?*, 7 CARBON & CLIMATE L. REV. 125, 134 (2013) (arguing that “the UNFCCC is best placed to provide for a generic framework on climate change”), with Jesse Reynolds, *Why the UNFCCC and CBD Should Refrain from Regulating Solar Climate Engineering*, in GEOENGINEERING OUR CLIMATE? ETHICS, POLITICS AND GOVERNANCE (Jason Blackstock & Sean Low eds., forthcoming 2017) (arguing that the UNFCCC, CBD, and other international forums should hold off on pursuing binding regulation of SRM for the foreseeable future).

83. United Nations Convention on the Law of the Sea, Dec. 10, 1982, 1833 U.N.T.S. 396 [hereinafter UNCLOS]. The “marine environment” is undefined in UNCLOS but scholars generally interpret it to include the marine

For example, “[s]tates have the obligation to protect and preserve the marine environment” and “to take . . . all measures consistent with this Convention that are necessary to prevent, reduce and control pollution of the marine environment from any source,” including from land-based sources.⁸⁴ However, interpretations of the Convention’s provisions in the SCE context are unclear. The UNCLOS’s definition of “pollution” could include both SCE as well as the global warming that SCE would counteract.⁸⁵

The Environmental Modification Convention (ENMOD) prohibits the hostile use of methods that implicitly include SCE.⁸⁶ Specifically, parties agree “not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party.”⁸⁷ At the same time, the agreement explicitly provides that it “shall not hinder the use of environmental modification techniques for peaceful purposes.”⁸⁸ Nevertheless, the terms “hostile” and “peaceful” are often in the eye of the beholder, and controversy regarding actions’ hostility could arise if drastic – even unintended – climactic effects are experienced in particular regions.⁸⁹ Enforcement also remains a hurdle, as ENMOD has no standing institutions, and aggrieved victims would need to bring complaints before the U.N. Security Council.⁹⁰

The parties to the Montreal Protocol on Substances that Deplete the Ozone Layer could choose to prohibit stratospheric injection, because atmospheric scientists believe that sulfate aerosols would catalyze ozone destruction.⁹¹ However, doing so would be problematic. Common industrial processes such as

atmosphere. See VERONICA FRANK, *THE EUROPEAN COMMUNITY AND MARINE ENVIRONMENTAL PROTECTION IN THE INTERNATIONAL LAW OF THE SEA: IMPLEMENTING GLOBAL OBLIGATIONS AT THE REGIONAL LEVEL* 12 (2007).

84. UNCLOS, *supra* note 83, arts. 192, 194, 207.

85. *Id.* art. 1.1(4).

86. Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, Dec. 10, 1976, 1108 U.N.T.S. 151 [hereinafter ENMOD]. ENMOD has been in force since 1978 and counts seventy-seven Parties, including the United States and almost all other major industrialized states.

87. *Id.* art. I.1.

88. *Id.* art. III.1.

89. See Horton & Reynolds, *supra* note 25, at 445.

90. ENMOD, *supra* note 86, art. V.

91. Montreal Protocol on Substances that Deplete the Ozone Layer, Sept. 16, 1989, 1522 U.N.T.S. 3.

the combustion of coal already emit sulfate aerosols in large quantities into the lower atmosphere.⁹² Thus, in order to regulate the stratospheric injection of sulfate aerosols, the Parties would need to define a *sui generis* controlled substance that would be based upon the location and/or the intention of its emission.

Likewise, stratospheric injection of sulfate aerosols from a single country's territory at the scale needed to induce a global climate response would violate the protocols to the Convention on Long-Range Transboundary Air Pollution (LRTAP Convention).⁹³ European and North American countries created this agreement in order to reduce and eliminate transboundary pollution, specifically the precursors to acid rain.⁹⁴ Three of its protocols place limits on countries' sulfate emissions.⁹⁵ Below such thresholds, which could include small- and moderate-scale SCE field tests, the LRTAP Convention Parties would be obligated to report their emissions and to consult with other Parties that are or at risk of being impacted.⁹⁶ However, it defines pollution much like the UNCLOS does, and consequently appears to encourage SCE in order to reduce the "pollution" of climate change.⁹⁷

The Parties to the Convention on Biological Diversity (CBD), a treaty with near global participation (but notably not the United States), agreed to a nonbinding statement of concern regarding climate engineering.⁹⁸ The statement

92. See S. J. Smith et al., *Anthropogenic Sulfur Dioxide Emissions: 1850–2005*, 11 *ATMOSPHERIC CHEMISTRY & PHYSICS* 1101 (2011).

93. Convention on Long-Range Transboundary Air Pollution art. 1, Nov. 13, 1979, 1302 U.N.T.S. 219 [hereinafter LRTAP Convention].

94. See generally *id.*

95. Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on the Reduction of Sulphur Emissions or Their Transboundary Fluxes by at Least 30 Per Cent, July 8, 1985, 1480 U.N.T.S. 215 [hereinafter Helsinki Protocol]; Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Further Reduction of Sulphur Emissions, June 13, 1994, 2030 U.N.T.S. 122 [hereinafter Oslo Protocol]; Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrophication and Ground-level Ozone, Nov. 30, 1999, 2319 U.N.T.S. 81 [hereinafter Gothenburg Protocol].

96. LRTAP Convention, *supra* note 93, arts. 5, 8; see also Helsinki Protocol, *supra* note 95, art. 4; Oslo Protocol, *supra* note 95, art. 5; Gothenburg Protocol, *supra* note 95, art. 7.

97. LRTAP Convention, *supra* note 93, art. 1(a).

98. Conference of Parties to the Convention on Biological Diversity, *Decision adopted by the Conference of the Parties to the Convention on*

requested that states not engage in such climate engineering activities that affect biodiversity until regulatory structures are in place, the risks are considered, and the activity is scientifically justified.⁹⁹ And as seen with the above multilateral agreements, SCE has the potential to both further the CBD's objectives (e.g. by helping conserve biological diversity) as well as to counter them (e.g. by posing risks to biodiversity).¹⁰⁰

As already noted, developing a regulatory regime for SCE will be challenging and will require quite some time. Climate change itself is politically contentious; reaching even modest international agreements has been a very lengthy process.¹⁰¹ SCE is, and probably will continue to be, especially contested. Elected political leaders and international negotiators presently have little incentive to develop international agreements to invest in and govern SCE research, particularly before the onset of significant adverse effects of climate change. SCE also remains a highly uncertain matter, in terms both of its expected effects and of states' positions on it. When such negotiating positions do begin to form, there may be a wide variance among countries. Finally, there is also a general "low appetite" for new multilateral agreements in the wake of the burst of international law making from the 1970s to the early 1990s.¹⁰²

B. A SOLAR CLIMATE ENGINEERING "MARKET"

In the absence of clearly applicable national and international law, national policies regarding IP often become the default regulatory regime for emerging technologies. Patents are legal mechanisms through which policy makers

Biological Diversity at Its Tenth Meeting, U.N. Doc. UNEP/CBD/COP/DECX/33/8(w) (Oct. 18–29, 2010).

99. *Id.*

100. Convention on Biological Diversity, art. 1, June 5, 1992, 1760 U.N.T.S. 79 [hereinafter CBD]; *see also id.* arts. 7(c), 8.

101. *See* Robinson Meyer, *The Still Unresolved Questions of the Paris Climate Agreement: A Guide to the Most Contentious Issues and How They're Discussed in the Agreement*, THE ATLANTIC (Dec. 10, 2015), <http://www.theatlantic.com/science/archive/2015/12/what-does-the-paris-agreement-say/419577/> (describing the most contentious terms of the Paris Agreement); *see also* Jesse Reynolds, *The International Regulation of Climate Engineering: Lessons from Nuclear Power*, 26 J. ENVTL. L. 269, 270 (2014) (“[O]bservers should be modest in their expectations of climate engineering’s international regulation, particularly through binding multilateral agreements.”).

102. Reynolds, *supra* note 101, at 286.

grant inventors temporally limited exclusive rights in order to incentivize the development of new inventions.¹⁰³ Patents incentivize disclosure to the public of technical information that might otherwise remain secret.¹⁰⁴ Similarly, trade secrecy laws protect inventors of valuable technical and commercial information from misappropriation by market competitors.¹⁰⁵ Competition (antitrust) law regulates companies when they bring products and services to the market, including research and innovation markets.¹⁰⁶ Thus, public authorities use the market and IP rights as another regulatory mode, in addition to more direct methods of funding innovation or of regulating products and processes.

In order to understand the current and probable future market in SCE, the structure and scale of the incentives for it must be considered. Abating GHG emissions (or many other types of pollution), implementing SCE, and conducting scientific research are each public goods, in that no one—including those who refuse to contribute to their costs and those who object—can be excluded from experiencing their effects.¹⁰⁷ Such public goods are generally produced at suboptimal quantities because a producer is unable to demand that those who enjoy them either pay or be excluded. Indeed, one of the primary functions of government is to provide public goods directly or to offer incentives for their production.

103. See ORG. FOR ECON. CO-OPERATION & DEV., PATENTS AND INNOVATION: TRENDS AND POLICY CHANGES 5 (2004) (“Changes in patent policy in OECD countries over the past two decades have fostered the use and enforcement of patents with the aim of encouraging investments in innovation and enhancing the dissemination of knowledge.”).

104. See John M. Olin, *The Disclosure Function of the Patent System (Or Lack Thereof)*, 118 HARV. L. REV. 2007, 2007 (2005) (stating that one main justification of the patent system is the dissemination of information).

105. See *Trade Secret*, CORNELL.EDU, https://www.law.cornell.edu/wex/trade_secret (last visited Oct. 25, 2016).

106. See, e.g., U.S. DEPT. OF JUSTICE & FED. TRADE COMM’N, ANTITRUST GUIDELINES FOR THE LICENSING OF INTELLECTUAL PROPERTY 10–11 (1995) [hereinafter DOJ & FTC ANTITRUST GUIDELINES], <https://www.justice.gov/sites/default/files/atr/legacy/2006/04/27/0558.pdf>.

107. Public goods are typically further defined as having effects whose enjoyment by one does not dilute the effects for others. Here, “good” is meant as something that is produced that satisfies the desires of some; it might be neither beneficial to all affected parties nor normatively good. In order for scientific research to be a public good, its results must be publicly available. See Jesse L. Reynolds, *An Economic Analysis of Liability and Compensation for Harm from Large-Scale Field Research in Solar Climate Engineering*, 5 CLIMATE L. 182, 186–89 (2015).

In terms of scale, the direct financial costs of the method of SCE—stratospheric aerosol injection—that presently appears to be the most inexpensive have been estimated on the order of U.S. \$25 to \$50 billion annually.¹⁰⁸ This implementation of SCE would roughly compensate for the warming effect of a doubling of the preindustrial atmospheric carbon dioxide concentration, a level that will be reached around 2060 at the current trajectory.¹⁰⁹ An industry with annual revenues of tens of billions of U.S. dollars is neither small nor enormous, approximately equivalent to the revenue of the world's 500th largest company.¹¹⁰ Even though this is within the reach of smaller states and of wealthy non-state actors, they would have no clear self-interest to assume this entire financial burden.¹¹¹ This is because, although the climate benefits of SCE implementation appear to be very large, they would be widely dispersed across the globe. For small to medium states and non-state actors, their benefits from SCE would be less than the implementation costs.¹¹² Furthermore, SCE may need to be

108. Paul J. Crutzen, *Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?* 77 CLIMATIC CHANGE 211, 212–13 (2006) (estimating the yearly cost at U.S. \$25–\$50 billion); Alan Robock et al., *Benefits, Risks, and Costs of Stratospheric Geoengineering*, 36 GEOPHYSICAL RES. LETTERS 1, 3 tbl.2 (2009) (estimating annual costs of up to U.S. \$30 billion); Justin McClellan et al., *Cost Analysis of Stratospheric Albedo Modification Delivery Systems*, ENVTL. RES. LETTERS, Aug. 30, 2012, at 1, 6 tbl.2 (2012) (estimating annual costs ranging from U.S. \$0.5 to U.S. \$390 billion depending upon the delivery system type); Ryo Moriyama et al., *The Cost of Stratospheric Climate Engineering Revisited*, in MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE (forthcoming 2016), <http://link.springer.com/article/10.1007/s11027-016-9723-y> (last visited Jan. 2, 2017) (estimating annual costs of up to U.S. \$10 billion).

109. See van Vuuren et al., *supra* note 13, at 23.

110. The 500th largest company is presently Old Mutual, with \$21 billion net sales in 2015. *Global 500*, FORTUNE, beta.fortune.com/global500/list (last visited Nov. 24, 2016).

111. Small states and non-state actors may have nonfinancial reasons to (try to) implement SCE. For example, states that are highly vulnerable to climate change impacts could use SCE as a means to encourage GHG emissions abatement by other states.

112. If we assume that climate change would cost 2% of countries' economic activity, then \$50 billion in annual implementation costs would be justified only for countries with a GDP of at least U.S. \$2.5 trillion, of which there are approximately six. This is only a rough estimate. See *GDP Ranking*, WORLD BANK (Oct. 3, 2016), <http://data.worldbank.org/data-catalog/GDP-ranking-table>; Douglas J. Arent et al., *Key Economic Sectors and Services*, in CLIMATE CHANGE 2014: IMPACTS, ADAPTATION, AND VULNERABILITY. PART A: GLOBAL AND SECTORAL ASPECTS. CONTRIBUTION OF WORKING GROUP II TO THE FIFTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE

maintained for a long period of time, as the injected aerosols would fall from the atmosphere within several months to a couple of years, causing the suppressed climate change to manifest at a dangerously rapid rate.¹¹³ Furthermore, implementation of global SCE could probably not remain clandestine. Satellite systems likely could detect large-scale field-testing or implementation of SCE, depending on factors such as the magnitude of the climatic intervention.¹¹⁴ It seems improbable that international and especially national authorities would tolerate an individual or non-state group under their jurisdiction or control modifying the world's climate without consent.

At the present time, the research activities conducted in advance of developing a market for SCE is driven primarily by public and private philanthropic research funders.¹¹⁵ The former group includes funding bodies of the European Union, the United Kingdom, Germany, China, Japan, Norway, and the United States.¹¹⁶ In general, public bodies—especially in the United States—provide little to no funding of SCE research. This may be due to SCE's controversial character and/or concerns that such support would be perceived as coming at the expense of GHG abatement efforts. To some extent, private funders have partially filled this vacuum. A small, dedicated fund established by Bill Gates dominates the latter.¹¹⁷ Considering SCE's speculative and controversial character, the current relative absence of private interest is unsurprising. As described in the following Part, patents are scarce and appear to be currently largely speculative. Research data is widely shared.

CHANGE 690 (2014), http://ipcc-wg2.gov/AR5/images/uploads/WGIAR5-Chap10_FINAL.pdf.

113. See Alan Robock et al., *Studying Geoengineering with Natural and Anthropogenic Analogs*, 121 CLIMATIC CHANGE 445, 448 (2013).

114. Dian J. Seidel et al., *Detection Limits of Albedo Changes Induced by Climate Engineering*, 4 NATURE CLIMATE CHANGE 93 (2014) (examining global and regional detection capabilities of SRM).

115. See *Geoengineering Research*, *supra* note 52 (“Our understanding is that there is a significant amount of academic interest in stratospheric aerosol injection.”).

116. See *id.* (follow link in section 3 titled “identify funded projects and funding sources around the world that explicitly include a significant solar geoengineering component”).

117. See *Fund for Innovative Climate & Energy Res.*, STANFORD.EDU, <http://dge.stanford.edu/labs/caldeiralab/FICER.html> (last visited Nov. 18, 2016).

As noted, SCE research efforts currently are largely state-supported activities.¹¹⁸ The early stage, costs, political contestation, uncertain results, and the public good character of SCE and its research may explain this.¹¹⁹ For the time being, research will probably remain largely within traditional public institutions such as government agencies (which might enlist private contractors for some R&D activities) and universities. Scientists' stated preference for public funding, particularly for more controversial outdoor SCE tests, may further limit private sector research. For example, those who wished to conduct what may become the first such outdoor test wrote that "we will only proceed with [the project] if it passes independent risk assessment and if it is financed predominantly with public funding from a relevant scientific agency."¹²⁰ However, additional interest from for-profit private actors may manifest if SCE becomes more certain and less contentious. As a report of the Royal Society stated, "[f]or SRM methods, a clear financial incentive does not yet exist, although there may be future income opportunities from publicly funded deployment (especially of proprietary technology)."¹²¹ Research funding and potential product or process patenting activity would consequently shift to private institutions. This would present both opportunities and challenges. As the Royal Society report also noted,

[t]his [commercial involvement] may be positive, as it mobilises innovation and capital, which could lead to the development of more effective and less costly technology at a faster rate than in the public sector. On the other hand, commercial involvement could bypass or neglect the socio-economic, environmental and regulatory dimensions of geoengineering.¹²²

With respect to SCE implementation, it is difficult to imagine a feasible scenario in which one or more states would *not* be the primary decision makers regarding whether and how

118. See *Geoengineering Research*, *supra* note 52.

119. See generally Garth Heutel et al., *Alternatives to Emissions Reduction: Using Climate Engineering to Tackle Global Warming*, VOXEU.ORG (June 4, 2016), <http://voxeu.org/article/climate-engineering-economics> (discussing the uncertainty and difficulties of climate engineering).

120. Dykema et al., *supra* note 18, at 15. This commitment is particularly noteworthy because the lead scientist for this proposal is one of the two scientists who make the final decisions regarding grants from the Gates fund, and is also among its beneficiaries. See *Fund for Innovative Climate & Energy Res.*, *supra* note 117.

121. SHEPHERD ET AL., *supra* note 23, at 44.

122. *Id.*

to implement such technologies, even if private entities owned and licensed the necessary technologies. Powerful governments would not likely tolerate the significant intentional alteration of their climates without their consent, although such consent could range from explicit to tacit. They would find or enact legal means to regulate such behavior within their jurisdiction or control. And they would also exert international pressure to ensure that SCE implementation by private actors in foreign jurisdictions was likewise controlled. In furtherance of the research, development, and possible implementation of SCE solutions, governmental actors would most likely need to procure products and services through new or existing procurement and bidding mechanisms. Such contracts could be lucrative.¹²³ Assuming that a handful of governments were involved in such contracts, public monopoly control of the market could tend to keep prices low, although rent-seeking behavior through activities such as lobbying by contractors is possible. In this way, a market for SCE could resemble that of the military equipment market, albeit at a smaller scale.

III. THE SOLAR CLIMATE ENGINEERING INTELLECTUAL PROPERTY LANDSCAPE

In this Part, we summarize the current landscape of IP protection for SCE technologies, focusing on patents, research data, and trade secrets, and offer a likely trajectory of such protection in the foreseeable future.

A. PATENTS

There are currently only a handful of patents that are clearly relevant to SCE. While numerous studies have been conducted with respect to patenting of “green” or “clean” technologies, broadly defined, few have focused specifically on SCE technology.¹²⁴ In 2014, Paul Oldham and colleagues

123. See, e.g., Press Release, Dep’t of Climate & Energy (U.K.), Government Unveils Eight Major New Renewables Projects, Supporting 8,500 Green Jobs (Apr. 23, 2014), <https://www.gov.uk/government/news/government-unveils-eight-major-new-renewables-projects-supporting-8500-green-jobs> (describing a twelve billion pound investment in renewable energy as a means of combatting climate change).

124. See, e.g., John H. Barton, *Intellectual Property and Access to Clean Energy Technologies in Developing Countries, An Analysis of Solar Photovoltaic, Biofuel and Wind Technologies*, in INT’L CTR. FOR TRADE AND SUSTAINABLE DEV. PROGRAMME ON TRADE AND ENVIRONMENT, TRADE AND SUSTAINABLE ENERGIE SERIES viii (2007), <http://ictsd.net/downloads/2008/11>

conducted an extensive survey of filed and issued patents “directly or indirectly related to climate engineering technologies” at the U.S. Patent and Trademark Office (USPTO) and the European Patent Office, and under the Patent Cooperation Treaty.¹²⁵ They considered all forms of climate engineering, including negative emissions (carbon dioxide removal) technologies; SCE was only a small portion of their resulting data set.¹²⁶ Oldham et al. identified twenty-eight patent families directly or indirectly related to SCE.¹²⁷ Likewise, Anthony Chavez recently conducted a review of USPTO records to determine “trends in applications for and granting of patents involving climate-engineering technologies,” and found eighteen SCE-related patents.¹²⁸ Like the data set of Oldham et al., that of Chavez included patents and applications that are directly or indirectly related to SCE and negative emissions technologies. We reviewed these sets of patents for their invocation of and their direct relevance to SCE, and we removed those that have or would have broader application and are only indirectly related to SCE.¹²⁹ We also conducted our own searches for additional SCE related patents and applications in early 2016, using similar terms and also

/intellectual-property-and-access-to-clean-energy-technologies-in-developing-countries_barton_ictsd-2007.pdf (discussing the relationship between IP and clean energy technology); JOHN M. LAZARUS, FOLEY & LARDNER LLP, CLEANTECH ENERGY PATENT LANDSCAPE: EXECUTIVE SUMMARY 1, 3, 6 (2010) (identifying the following clean tech categories: solar, wind, hydro/wave/tidal, geothermal, biomass/biogas/biofuel, nuclear, hybrid vehicles, fuel cells for hybrid vehicles, utility metering, smart grid, and CO₂ storage or sequestration); U.N. ENVTL. PROGRAMME, EUR. PATENT OFFICE & INT’L CTR. FOR TRADE & SUSTAINABLE DEV., PATENTS AND CLEAN ENERGY: BRIDGING THE GAP BETWEEN EVIDENCE AND POLICY: FINAL REPORT 9 (2010), http://www.eurosfair.prdd.fr/7pc/doc/1308064085_patents_clean_energy_study_en.pdf (mapping patents as a part of global GHG abatement innovations); Antoine Dechezleprêtre et al., *Invention and Transfer of Climate Change-Mitigation Technologies: A Global Analysis*, 5(1) REV. ENVTL. ECON. & POL’Y 109, 109–10 (2011), <http://reep.oxfordjournals.org/content/5/1/109.full.pdf> (discussing GHG abatement inventions); Joy Y. Xiang, *Addressing Climate Change: Domestic Innovation, International Aid and Collaboration*, 5 N.Y.U. J. INTELL. PROP. & ENT. L. 1, 24–36 (2016) (summarizing empirical studies).

125. Oldham et al., *supra* note 20, at 1, 9–15; *see also* Anthony E. Chavez, *Exclusive Rights to Saving the Planet: The Patenting of Geoengineering Inventions*, 13 NW. J. TECH. & INTELL. PROP. 1, 9–12 (2015) (discussing the rise in geoengineering patent applications).

126. Oldham et al., *supra* note 20, at 3.

127. *Id.* at 1.

128. Chavez, *supra* note 125, at 9.

129. *See infra* note 145 and accompanying text.

checking subsequent applications or patents that cited to earlier-filed, relevant patents or applications. As discussed below, we have also assessed (where available) information on patent ownership. We focused on whether the patents or applications were (at the time of relevant publication) subject to government rights; whether they were owned by universities, private firms, or individuals; and whether owners' professional affiliations could be identified.

Together, our subsequent review, research, and scrutiny resulted in finding thirty-three inventions reflected in various patents and patent applications that are directly related to SCE (see Table 1 below, grouped by category of technology and then by status). We chose to list patents and applications by the number of inventions for two reasons. First, because of the territorial scope of patents, counting patents or applications for the same technology in multiple patents or applications issued or filed in multiple countries would appear to suggest a significantly higher number of inventions than actually may have been made. Second, inventors often file multiple chains of applications relating to the same invention, either to obtain different patent claims or to continue prosecution concerning the same invention, while earlier applications are pending or after "final" rejections of particular applications.¹³⁰ Such "continuation" applications if listed separately would appear to suggest many more inventions than actually were made.¹³¹ Note that the dates listed in Table 1 are the dates of the actual applications, and not of any priority claim that may have been made to earlier applications.

Of the thirty-three inventions that we identified, seven were issued at least one patent that appears to remain in force in some jurisdiction.¹³² Five inventions were issued at least one patent that has since expired and no other patent has yet issued. Fourteen applications were ultimately abandoned by

130. These applications often claim priority back to earlier applications. See, e.g., 35 U.S.C. §§ 119, 120, 121 (2012).

131. This would be the case whether or not the applications contain additional disclosures, and particularly when filed in multiple jurisdictions. For similar reasons, Oldham focused on "first filings"—while also discussing "family members"; Chavez focused on applications and grants only in the United States since 2011. See Oldham et al., *supra* note 20, at 4; Chavez, *supra* note 125, at 7 & n.72.

132. However, additional applications may yet result in patents in other jurisdictions or further patents for the same invention in the same jurisdiction.

their applicants without any grant of a patent, whether because the relevant patent office had indicated the invention was not patentable or the applicant chose not to pursue the matter further. Finally, seven inventions remain pending in the form of at least one application in some jurisdiction as of late 2016 (and may include additional applications pending in the same or other jurisdictions).¹³³

We note that some inventions had more than one patent issue for that invention but originated as “divisional,” “continuation,” or otherwise closely related applications. We have not listed in Table 1 the additional granted patents in these families that we thought were too closely related.¹³⁴ Rather, we have listed only the first-granted patent for the same invention, as understood per the discussion above.

Seventeen of the thirty-three patents or applications listed in Table 1 relate to space- and surface-based SCE. These proposed techniques are widely considered prohibitively expensive, of limited capacity, and/or infeasible.¹³⁵ That leaves sixteen patent applications (some of which have gone abandoned) and granted patents concerning the two proposed SCE techniques that are currently considered relatively feasible and effective: aerosol injection and marine cloud brightening.¹³⁶ Among these, four were issued and remain active, one was issued and has since expired, nine have been abandoned, and two are still pending as applications.¹³⁷ Furthermore, several of the applications related to aerosol injection use materials or methods that are not considered viable among mainstream SCE scientists. Specifically, one inventor has one pending application and one issued patent for SCE inventions that address injecting materials into the lower

133. *See infra* Table 1.

134. We have also not listed any of the related applications, in the same or other jurisdictions, whether now abandoned or that may remain pending.

135. *See* NAT'L RESEARCH COUNCIL OF THE NAT'L ACADS. ET AL., *supra* note 15, at 128 (stating that “the committee has chosen to not consider these technologies because of the substantial time (>20 years), cost (trillions of dollars), and technology challenges associated with these issues,” and concluding that surface albedo “techniques are judged to be of low potential use on the global scale because of generally low effectiveness and high costs”).

136. *See, e.g.*, PCT Pat. Appl. No. PCT/US2013/020589, Publ'n No. WO2013086542A1 (June 13, 2013) (detailing a system for spraying salt water to create cloud brightening droplets).

137. *See infra* Table 1.

atmosphere (the troposphere, not the stratosphere).¹³⁸ This inventor has not published in the academic literature. Interestingly, though many of these patents and patent applications were filed in the United States, none appears to have resulted from research conducted at U.S. research universities or using U.S. federal research funding.¹³⁹

Of the patents and applications they studied, Oldham et al. concluded, “[w]hile patent activity [currently] appears to be minor it merits further research using an approach focusing on capturing activity by individual companies and inventors.”¹⁴⁰ Having conducted our own review, we concur.

138. See, e.g., WO2008006364A2 and US5003186A, US7501103B2 (created by Franz Dietrich Oeste and describing the addition of substances to fuels so that the smoke resulting from their combustion cools the lower atmosphere).

139. This result has implications for the rights of the U.S. Government under the Bayh-Dole Act, among other things. See *infra* Subsection V.A.2.

140. Oldham et al., *supra* note 20, at 14.

Table 1. SCE Related Patents and Patent Applications as of Early 2016

Technique ¹⁴¹	Status	Publication, Application, or Patent Number	First Inventor	Filing Year	Name
AI	Issued (2009)	US7501103B2	Oeste	2002	Tropospheric volume elements enriched with vital elements and/or protective substances
AI	Issued (2012)	US8166710B2	Chan	2007	High altitude structures for expelling a fluid stream through an annular space
AI	Issued (2012)	US8152091B2	Jenkins	2008	Production or distribution of radiative forcing agents
AI	Issued (2013)	GB2476518	Davidson	2010	Atmospheric delivery system
AI	Issued (1991) [expired]	US5003186A	Chang	1990	Stratospheric Welsbach seeding for reduction of global warming

141. AI = aerosol injection; MC = marine cloud brightening; Sp = Space-based; Su = surface-based.

Technique¹⁴¹	Status	Publication, Application, or Patent Number	First Inventor	Filing Year	Name
AI	Application pending	WO2008006364A2	Oeste	2007	Combustibles and smoke mixtures for cooling the climate, and devices for the production of such a smoke mixture
AI	Abandoned	DE10217932A1	Oeste	2002	Safety device comprises a unit for burning fuels and fuel additives, in which the combustion products contain iodine, iron, carbon, soot, aerosol-like iron oxides, gaseous iodine compounds and absorbed iodine compounds
AI	Abandoned	US20090032214A1	Hucko	2008	System and Method of Control of the Terrestrial Climate and its Protection against Warming and Climatic Catastrophes Caused by Warming such as Hurricanes
AI	Abandoned	DE102009004281A1	Oeste	2009	Ferrous aerosol emission method for self-releasing cooling of atmosphere, involves adding compound of iron and/or bromine and/or chlorine to solid fuel and/or gas fuel and mixing flue gases of solid fuel and/or gas fuel

Technique ¹⁴¹	Status	Publication, Application, or Patent Number	First Inventor	Filing Year	Name
AI	Abandoned	DE102009059005A1	Meyer-Oeste ¹⁴²	2009	Air cooling with ferrous salt mixture aerosols
AI	Abandoned	US20100127224A1	Neff	2009	Atmospheric injection of reflective aerosol for mitigating global warming
AI	Abandoned	US20110005422A1	Trimberger	2009	Method and Apparatus for Cooling a Planet
AI	Abandoned	US20120117003A1	Benaron	2010	Geoengineering Method Of Business Using Carbon Counterbalance Credits

142. Franz Dietrich Meyer-Oeste is the same person as Franz Dietrich Oeste.

Technique ¹⁴¹	Status	Publication, Application, or Patent Number	First Inventor	Filing Year	Name
AI	Abandoned	DE102011108433A1	Gleich	2011	Method for controlled cooling of troposphere by its enrichment, involves containing iron element in form of salt, salt solution, hydroxide, oxide hydrate or oxide in aerosol, and vaporous hydrophobic ferrous material is added to atmosphere
AI	Abandoned	US20110284690A1	Puckett	2011	Utility Device System For Releasing Or Capturing Disbursements For The Atmosphere By Means Of An Aircraft
MC	Application pending	WO2013086542A1	Foster	2013	Salt water spray systems for cloud brightening droplets and nano-particle generation
Sp	Issued (2016)	US9491911B2	Stelmack	2014	Method for modifying environmental conditions with ring comprised of magnetic material
Sp	Issued (2016)	US9457919B2	Bradley	2015	Climate-regulating-system

Technique ¹⁴¹	Status	Publication, Application, or Patent Number	First Inventor	Filing Year	Name
Sp	Issued (1971) [expired]	US3564253A	Buckingham	1967	System and method for irradiation of planet surface areas
Sp	Issued (1998) [expired]	US5762298A	Chen	1995	Use of artificial satellites in earth orbits adaptively to modify the effect that solar radiation would otherwise have on earth's weather
Sp	Issued (1999) [expired]	US5984239A	Chen	1998	Weather modification by artificial satellites
Sp	Issued (2000) [expired]	US6045089A	Chen	1999	Solar-powered airplane
Sp	Application pending	WO2013077557A1	Choi	2013	Method for controlling land surface temperature using stratospheric airships and reflector
Sp	Abandoned	WO1990010378A1	Nakagawa	1990	Protective apparatus

Technique ¹⁴¹	Status	Publication, Application, or Patent Number	First Inventor	Filing Year	Name
Sp	Abandoned	GB200700106D0	Wakefield	2007	A global warming solution
Sp	Abandoned	US20080203328A1	Palti	2008	Outer space sun screen for reducing global warming
Sp	Abandoned	US20100252647A1	Ace	2009	Benign global warming solution offers unprecedented economic prosperity
Su	Issued (2011)	US8033879B2	Lambert	2009	Biophysical geoeengineering compositions and methods
Su	Application pending	DE102007018168A1	Brosig	2007	Process and assembly for short-term modification of earth's climate in accordance with diurnal rhythm
Su	Application pending	CA2701824A1	Field	2008	Systems for environmental modification with climate control materials and coverings

Technique ¹⁴¹	Status	Publication, Application, or Patent Number	First Inventor	Filing Year	Name
Su	Application pending	CN101574050A	Kong	2008	Method and device of utilizing solar energy to manually adjust climate
Su	Application pending	WO2010144672A1	Narayanamurthy	2010	Method and structure for a cool roof by using a plenum structure
Su	Abandoned	GB2438156A	Harvey	2006	Climate regulating solar reflector

The results of the patent survey thus do not imply that all existing SCE granted patents and technologies disclosed in patent applications are and will remain unimportant, nor that they will avoid creating complications for the future research, development, and possible implementation of SCE.¹⁴³ Currently pending patent applications containing broadly applicable claims ultimately may be granted; patented methods that now appear marginal could become central; early patents that are not being practiced could later become essential; and more applications for technologies and approaches could be filed. Further, not only university scientists but also commercial entities are filing applications for SCE patents, including non-practicing entities that are known for affirmatively licensing and occasionally litigating their patent portfolios.¹⁴⁴ Finally, there may be many other general-purpose, patented technologies that could have uses in SCE, but whose patents do not describe SCE applications. They thus did not appear in or were removed from prior patent reviews and our review.¹⁴⁵ We have not attempted to search for such generally applicable technologies in regard to presently understood SCE methods, much less in regard to those that may be developed in the future. Nevertheless, the relative paucity of patents that are directly related to SCE at present provides a unique opportunity to consider means that might avoid the development of problems that they might engender.¹⁴⁶

To better understand the patent landscape, some granted patents and patent applications related to SCE warrant elaboration. First, the inventors and the applicant (assignee) of a pending application for an invention related to marine cloud brightening (WO2013086542A1, "Salt Water Spray Systems for Cloud Brightening Droplets and Nano-Particle Generation"¹⁴⁷) are all published SCE researchers.¹⁴⁸ The applicants describe

143. See *infra* Part IV.

144. See Jim Kerstetter & Josh Lowensohn, *Inside Intellectual Ventures, the Most Hated Company in Tech*, C/NET (Aug. 21, 2012), <http://www.cnet.com/news/inside-intellectual-ventures-the-most-hated-company-in-tech/>.

145. See generally SHEPHERD ET AL., *supra* note 23 (discussing many of these technologies).

146. See Oldham et al., *supra* note 20, at 14 (noting "very limited activity in this field").

147. PCT Appl. No. PCT/US2013/020589, Publ'n No. WO2013086542 A8 (May 21, 2015).

148. See Latham et al., *supra* note 44; Gary Cooper et al., *A Review of Some Experimental Spray Methods for Marine Cloud Brightening*, 4 INT'L J.

the relevant technology as “being particularly useful for geoengineering for increasing cloud reflectivity.”¹⁴⁹ Thus, the applicants recognize these generally applicable technologies as having specific uses in SCE, but as not being limited to such uses.

Second, two researchers who assigned their rights to the Hughes Aircraft Company (which has since been purchased by the Raytheon Company) applied for and were granted a U.S. patent that appears to be related to stratospheric aerosol injection in 1991.¹⁵⁰ The patent has now expired. The claims of this early patent were worded broadly. The first of two independent claims was for “reducing atmospheric warming [by] . . . dispersing tiny particles of a material . . . [which] provide a means for converting infrared heat energy into far infrared radiation which is radiated into space.”¹⁵¹ This method likely would not apply to stratospheric aerosol injection, because—as presently envisioned—the aerosols would reflect some incoming solar radiation back to space.¹⁵² In contrast, the patent describes particles that, if they were to function properly, would absorb near infrared wavelength energy and re-emit them as far infrared wavelength energy.¹⁵³

Third, Robert Theodore Jenkins (a former Intel engineer) applied for and was granted two patents (one being a divisional application of the original filing) for the “[p]roduction or distribution of radiative forcing agents.”¹⁵⁴ These patents cover specific methods of delivering aerosols to the upper atmosphere.¹⁵⁵ The claims of the first patent address a vehicle that produces the cooling agent through heat.¹⁵⁶ For one

GEOSCIENCES 78 (2013); Gary Cooper et al., *Preliminary Results for Salt Aerosol Production Intended for Marine Cloud Brightening, Using Effervescent Spray Atomization*, 372 PHIL. TRANSACTIONS ROYAL SOC’Y A (Theme Issue No. 2031) 1 (2014); Armand Neukermans et al., *Sub-Micrometer Salt Aerosol Production Intended for Marine Cloud Brightening*, 142 ATMOSPHERIC RES. 158 (2014).

149. PCT Appl. No. PCT/US2013/020589, Publ’n No. WO2013086542 A8 (May 21, 2015).

150. U.S. Patent No. 5,003,186 (issued Mar. 26, 1991).

151. *Id.* at claim 1.

152. *Id.* § 2.

153. *Id.* § 4.

154. U.S. Patent No. 8,152,091 B2 (issued Apr. 10, 2012); U.S. Patent No. 8,944,363 B2 (issued Feb. 3, 2015).

155. U.S. Patent No. 8,152,091 B2 (issued Apr. 10, 2012); U.S. Patent No. 8,944,363 B2 (issued Feb. 3, 2015).

156. *See* U.S. Patent No. 8,152,091 B2 claims 1, 19 (issued Apr. 10, 2012).

example, this patent could cover an engine that burns aviation fuel with a high sulfur content, producing sulfate aerosols.¹⁵⁷ The claims of the second patent address vehicles that have “control surfaces” to distribute cooling agents from “two or more constituents” or that can be maneuvered to deliver such cooling agents in response to atmospheric conditions.¹⁵⁸ The second patent was partially assigned to TVG, LLC of Oregon, USA.¹⁵⁹ However we have listed only the first in Table 1 and in our count of inventions that have been granted at least one patent, as we view these as closely related technologies.

Fourth, a granted patent (with numerous pending patent applications that are not listed in Table 1) for a conduit, “High altitude structures and related methods,” notes that

[b]y controlling the amount and type of gasses and/or particulate placed into the atmosphere, it may be possible to control to some extent the heating of the Earth. Delivery of such gasses and/or particulate may be provided by the use of high altitude conduit systems, such as are described here.”¹⁶⁰

Some of the application’s inventors published early white papers on SCE.¹⁶¹ Another named inventor in this application is Nathan P. Myhrvold, a co-founder of Intellectual Ventures (IV), one of the largest non-practicing, patent-holding entities.¹⁶² The patent application is assigned to a corporation that has been described as a shell company of IV, with which it

157. *Id.*

158. *See* U.S. Patent No. 8,944,363 claims 1, 16, 18, 19 (issued Feb. 3, 2015).

159. *Id.*

160. U.S. Patent No. 8166710, at col. 6, l. 5 (issued May 1, 2012).

161. *See* EDWARD TELLER ET AL., ACTIVE CLIMATE STABILIZATION: PRACTICAL PHYSICS-BASED APPROACHES TO PREVENTION OF CLIMATE CHANGE (2002); EDWARD TELLER ET AL., GLOBAL WARMING AND ICE AGES: I. PROSPECTS FOR PHYSICS-BASED MODULATION OF GLOBAL CHANGE (1997).

162. *See The Partial List of Non-Practicing Entities Featured in the NPE Tracker*, IP CHECKUPS, <http://www.ipcheckups.com/npe-tracker/npe-tracker-list/> (last visited Nov. 19, 2016) (noting about 40,000 patents in IV’s portfolio).

shares an address.¹⁶³ IV claims that it does not intend to profit from the patent.¹⁶⁴

Fifth, another international application resulted in a number of patents in England and more recently resulted in a patent in the United States (e.g., GB2476518, GB2487287, US9353954), for an “Atmospheric Delivery System” including a conduit “for transporting and dispersing particles into the earth’s stratosphere, particularly to achieve a global or local cooling effect.”¹⁶⁵ That application was one of the concerns triggering cancellation of the 2012 United Kingdom field trial.¹⁶⁶ These applicants appear to have assigned their rights to a spin-off company created by one of the researchers who is also a named inventor.¹⁶⁷ One of the patent holders stated that he did not expect the venture to be profitable, but that if it were profitable, the owners would donate the revenue to “climate-change-related charities.”¹⁶⁸ He claimed to have filed this application in order to prevent others, especially “ExxonMobil or Shell,” from doing so.¹⁶⁹ This approach raises the issues (discussed further in Parts IV and V below) of defensive patenting and publication as means to create prior art, preventing patent rights from issuing to subsequent inventors, and of using patents defensively to countersue others who seek to assert patents in a particular field.

163. Tom Ewing & Robin Feldman, *The Giants Among Us*, 2012 STANFORD TECH. L. REV. 1, 38; *see also* U.S. Patent Application No. 11/788,383, Publ’n No. US20080257977A1 (filed Apr. 18, 2007) (listing Searete LLC as the correspondence address); U.S. Patent Application No. 11/788,372, Publ’n No. US2008/0258006 A1 (filed Apr. 18, 2007) (listing Searete LLC as the correspondence address); U.S. Patent Application No. 12/589,504, Publ’n No. US2010/007177 1A1 (filed Oct. 22, 2009) (listing Searete LLC as the correspondence address).

164. Press Release, Intell. Ventures, Intellectual Ventures’ Answers About Geoengineering (Oct. 23, 2009), <http://www.intellectualventures.com/news/press-releases/intellectual-ventures-answers-about-geoengineering/> (claiming “we do not expect or intend that our climate technology inventions will make money”).

165. U.K. Patent No. GB2487287 (published Apr. 24, 2013), at 1, ll. 7–8.

166. *See* Cressey, *supra* note 55; *see also infra* text accompanying note 264.

167. U.K. Patent No. GB2487287 (published Apr. 24, 2013) (listing “Davidson Technology Limited” as the “Proprietor[],” i.e., the owner).

168. Cressey, *supra* note 55.

169. Michael Marshall, *Controversial Geoengineering Field Test Cancelled*, NEW SCIENTIST (May 22, 2012), <https://www.newscientist.com/article/dn21840-controversial-geoengineering-field-test-cancelled/>.

Sixth, one abandoned patent application was for an SCE business method.¹⁷⁰ Specifically, the application claimed a “business method for providing commercial value to a geoengineering global cooling business” involving four steps: (1) manufacturing a “device or agent designed to reduce the incident energy upon the Earth”; (2) deploying the device; (3) receiving compensation in the form of a credit for reducing incident energy; and (4) selling the credit for other valuable consideration.¹⁷¹ The patent thus would seek to address GHG abatement measures through SCE approaches that would be recognized within, among other things, carbon emission trading markets.

In summary, the patent landscape for SCE currently indicates a general low level of patent activity, particularly by published, university-based SCE researchers and for SCE proposals that are within the mainstream of SCE research. This is remarkable, considering the potential development of an industry that could have direct annual revenues on the order of \$50 billion.¹⁷² Further, our research, building upon the work of Oldham et al. and Chavez, reveals that ownership of SCE-related patents and patent applications is diverse. Parties to whom applications or issued patents were assigned (at the time of relevant publication) include individual inventors, university scientists (with some assignments to their research institutions or to spinoff companies), non-practicing entities, and one large corporation.¹⁷³

As a final note, the line distinguishing SCE and non-SCE patenting activity is far from clear.¹⁷⁴ As noted, research in unrelated areas may yield innovations that are later important or even essential to SCE research, development, or implementation.¹⁷⁵ Likewise, SCE work may lead to patents

170. U.S. Patent Application No. 12/942,701, Publication No. US2012/0117003 A1 (filed Nov. 9, 2010).

171. *Id.* at claim 1.

172. *See supra* notes 108–09 and accompanying text.

173. *See, e.g.*, U.S. Patent No. 8,152,091 B2 (issued Apr. 10, 2012); U.S. Patent No. 8,944,363 B2 (issued Feb. 3, 2015); U.S. Patent Application No. 11/788,389, Publ’n No. US2008/0257396 A1 (issued Oct. 23, 2008).

174. *See, e.g.*, Ken Caldeira and Katharine L. Ricke, Correspondence, *Prudence on Solar Climate Engineering*, 3 NAT. CLIMATE CHANGE 941 (2013) (“The phrase ‘field test of solar climate engineering’ cannot be unambiguously defined.”).

175. *See* Megan Herzog & Edward A. Parson, *Moratoria for Global Governance and Contested Technology: The Case of Climate Engineering* 13–14

that are used largely or entirely in other domains.¹⁷⁶ Furthermore, given SCE's controversy, researchers may attempt to conceal their SCE work by describing it in other terms, such as by discussing uses for aerosols, clouds, or climate in general. Consequently, some patents and patent applications that were developed with SCE in mind may not be described as such and may not have been identified in Oldham et al.'s, Chavez's, or our research.

B. RESEARCH DATA AND TRADE SECRETS

The present state of sharing research data among SCE scientists is difficult to specify with precision. Informal inquiries made by the authors to various SCE researchers produced responses consistently indicating that they readily share data when asked, and often place their results into standardized, publicly accessible databases. For example, the largest SCE modeling program—the Geoengineering Model Intercomparison Project (GeoMIP)—converts its output into a format consistent with the Coupled Model Intercomparison Project, the leading standard for data from coupled atmosphere-ocean general circulation models.¹⁷⁷ The results from GeoMIP are freely available online through the Earth System Grid.¹⁷⁸ The only contingency is that, if research data is

(UCLA Sch. of Law, Pub. Law Research Paper No. 16–17, 2016) (discussing the overlap between general climate research and SCE field tests).

176. John Latham et al., *Climate Engineering: Exploring Nuances and Consequences of Deliberately Altering the Earth's Energy Budget*, 372 PHIL. TRANSACTIONS ROYAL SOC'Y A (Theme Issue No. 2031) 3 (2014) (describing SCE experiments that provide co-benefits for more general climate science).

177. See Ben Kravitz, *GeoMIP Data*, GEOENGINEERING MODEL INTERCOMPOSITION PROJECT, <http://climate.envsci.rutgers.edu/GeoMIP/data/GeoMIP-data-submission.doc> (last visited Nov. 19, 2016); Interview with Ben Kravitz, Founder and Coordinator, GeoMIP. GeoMIP is a publicly funded international collaboration that has been endorsed by the Working Group on Coupled Modeling of the World Climate Research Programme. Ben Kravitz, *GeoMIP Support*, GEOENGINEERING MODEL INTERCOMPOSITION PROJECT, <http://climate.envsci.rutgers.edu/GeoMIP/support.html> (last visited Nov. 19, 2016); *WCRP Coupled Model Intercomparison Project*, WORLD CLIMATE RES. PROGRAMME, http://www.wcrp-climate.org/wgcm/cmip_coord.shtml (last visited Nov. 19, 2016).

178. See *Project: GeoMIP*, EARTH SYSTEM GRID AT NCAR, <https://www.earthsystemgrid.org/project/geomip.html> (last visited Nov. 19, 2016). The Earth System Grid is an online research data gateway. It is governed by the Earth System Grid Federation, an international collaboration that primarily supports the World Climate Research Programme, a program of the United Nations World Meteorological Organization. The Earth System Grid Federation is led by the U.S. National Center for Atmospheric Research,

used for publication “within a certain time window,” the original modelers should be offered the opportunity to contribute as co-authors.¹⁷⁹ “Each modeling group is well posed to understand its model and the intricacies of performing the GeoMIP experiments, so their perspectives will undoubtedly be useful.”¹⁸⁰

Researchers in the broader climatology and earth science disciplines participate in a number of international data sharing initiatives and programs. These include the GEOSS Common Infrastructure developed by the Group on Earth Observations (GEO)¹⁸¹ and the intergovernmental Belmont Forum’s E-Infrastructure for Global Change Research.¹⁸²

Researchers, both at universities and private firms, might develop and maintain trade secrets relating to SCE.¹⁸³ This could be with the intention of later development into commercially viable technologies or for potentially valuable business advantages in providing services to support SCE research, development, or implementation activities. Unlike patents, however, trade secrets are not registered or recorded with any governmental agency.¹⁸⁴ There is thus no way to determine the extent to which such valuable information may

and is supported by the U.S. National Science Foundation, Department of Energy, National Oceanic and Atmospheric Administration, and National Aeronautics and Space Administration. It closely collaborates with the E.U. Common Metadata for Climate Modelling Digital Repositories. *About the Earth System Grid*, EARTH SYSTEM GRID AT NCAR, <https://www.earthsystemgrid.org/about/overview.htm> (last visited Nov. 19, 2016).

179. See Kravitz, *GeoMIP Data*, *supra* note 177.

180. *Id.*

181. *The GEOSS Common Infrastructure*, GROUP ON EARTH OBSERVATIONS, https://www.earthobservations.org/gci_gci.shtml (last visited Nov. 19, 2016).

182. See *About: Belmont Forum e-Infrastructures and Data Management Collaborative Research Action: Establishing Sustainable e-Infrastructures for Global Change Research*, BELMONT F., <http://www.bfe-inf.org/info/about> (last visited Nov. 19, 2016).

183. Lawrence Kogan, President, Inst. for Trade, Standards, and Sustainable Dev., Climate Change Technology Transfer or Compulsory License?: Speech Presented at The American National Standards Institute (ANSI) Monthly Caucus Luncheon 6 (Jan. 15, 2010) (“The ‘Global Access Principles’ of such funding structures would set forth rules for the international management of [IP rights] (e.g., patents, trade secrets, copyrights, plant breeders’ rights) developed as the result of international collaborations or research grants.”) (emphasis omitted).

184. See *Trade Secret Policy*, U.S. PAT. & TRADEMARK OFF., <https://www.uspto.gov/patents-getting-started/international-protection/trade-secret-policy> (last visited Nov. 19, 2016).

be developed, by whom, and with what intentions.¹⁸⁵ However, our informal inquiries of some university researchers indicate that they are not presently considering preserving their SCE discoveries as trade secrets. Further, because of the lack of current commercial development and implementation of SCE technologies, any such trade secrets are likely nascent. Nevertheless, the abandoned patent application for a business method in trading credits from manufacturing and deploying cooling devices (described above¹⁸⁶) would certainly suggest that the commercial potential of some SCE technologies or related business practices may make trade secret acquisition and maintenance attractive in the future.

IV. INTELLECTUAL PROPERTY CHALLENGES FOR EMERGING TECHNOLOGIES

IP will form an important part of the SCE governance landscape. In this Part, we address a number of common concerns relating to IP protection in emerging markets, with a particular emphasis on implications for SCE research.

A. PATENTS AND INNOVATION IN EMERGING MARKETS

Diverse views exist as to the purpose of IP rights in general, and patent rights in particular,¹⁸⁷ and there are many different approaches to understanding how they function. Because innovation can be considered a public good, and because others can use information—once publicly known—for their benefit without paying for it, IP rights are often understood as a means to overcome Arrow's information paradox.¹⁸⁸ As applied to patent law, the government's grant of

185. See generally James Pooley, *Trade Secrets: The Other IP Right*, WIPO MAG., (June 2013), http://www.wipo.int/wipo_magazine/en/2013/03/article_0001.html.

186. See *supra* note 170 and accompanying text; see also Andrew Lockley, *Licence to Chill: Building a Legitimate Authorisation Process for Commercial SRM Operations*, 18 ENVTL. L. REV. 25 (2016) (describing potential linkages between SCE and voluntary carbon offset markets).

187. See Richard D. Nelson & Robert Mazzoleni, *Economic Theories About the Costs and Benefits of Patents*, in INTELLECTUAL PROPERTY RIGHTS AND RESEARCH TOOLS IN MOLECULAR BIOLOGY 17, 17–18 (1997) (discussing four main theories of IP rights).

188. See Kenneth J. Arrow, *Economic Welfare and the Allocation of Resources for Invention*, in THE RATE AND DIRECTION OF INVENTIVE ACTIVITY: ECONOMIC AND SOCIAL FACTORS 609, 614–16 (Univs.-Nat'l Bureau Comm. for Econ. Research, Comm. on Econ. Growth of the Soc. Sci. Research Council, ed. 1962). But see Michael J. Burstein, *Exchanging Information Without*

temporary exclusive rights is believed to provide incentives to invent new technologies that benefit society that would otherwise not have been produced because of the inability to protect the information, and to thereby recoup the investments made in producing it.¹⁸⁹ Patents also induce disclosure of information for immediate use in further innovative activities, as compared to protecting such information through secrecy.¹⁹⁰

Patents, however, impose static costs to society in the form of increased prices (if the patented invention has sufficient market power) and dynamic costs to innovation (when the patent rights raise the costs of or foreclose sequential innovation).¹⁹¹ Some view patents as appropriately providing exclusive rights to control such sequential innovation research “prospects,” thereby allowing the patent holder to develop sequential innovation more efficiently without the social costs of duplicative efforts.¹⁹² Without wading deeply into an unsettled debate over which theories of patents best reflect historical justifications or actual operations, it suffices to note that patent rights have historically led to some significant conflicts. Moreover, many scholars believe that patents are more important for developing technologies to the point of marketable products, and less important for basic research that governments typically fund in the first instance.¹⁹³

Further, the optimal scope and duration of patent rights is also subject to debate,¹⁹⁴ with its resolution having significant

Intellectual Property, 91 TEX. L. REV. 227(2012) (arguing that IP is not necessary to overcome Arrow’s paradox).

189. See, e.g., Arnold Plant, *The Economic Theory Concerning Patents for Inventions*, 1 ECONOMICA 30, 38–40, 43–44 (1934).

190. This is the case at least for innovations that are not self-disclosing or are not easy to reverse engineer. See generally Katherine J. Strandburg, *What Does the Public Get? Experimental Use and the Patent Bargain*, 2004 WISC. L. REV. 81, 111–17 (2004) (discussing self-disclosing and non-self-disclosing inventions).

191. See, e.g., Suzanne Scotchmer, *Standing on the Shoulders of Giants: Cumulative Research and Patent Law*, 5 J. ECON. PERSP. 29, 33–34 (1991).

192. See, e.g., John F. Duffy, *Rethinking the Prospect Theory of Patents*, 71 U. CHI. L. REV. 439, 465 (2004); Edmund W. Kitch, *The Nature and Function of the Patent System*, 20 J.L. & ECON. 265, 278 (1977).

193. See *infra* notes 229–42 and accompanying text.

194. See, e.g., Robert P. Merges & Richard R. Nelson, *On the Complex Economics of Patent Scope*, 90 COLUM. L. REV. 839 (1990) (arguing for a reduction in patent scope); Richard J. Gilbert & Carl Shapiro, *Optimal Patent Length and Breadth*, 21 RAND J. ECON. 106 (1990) (presenting models to reduce “deadweight loss” associated with patent scope and duration); Vincenzo Denicolò, *Patent Races and Optimal Patent Breadth and Length*, 44 J. INDUS.

consequences. Broad initial patent rights in “pioneering” (foundational) discoveries and technologies can preclude sequential competitive innovation and development.¹⁹⁵ For this reason, three U.S. Supreme Court Justices have argued that the historic, current, and universally acknowledged exclusion from patent systems of patents on basic scientific and natural discoveries—“laws of nature, physical phenomena, and abstract ideas”¹⁹⁶—was based on utilitarian concerns that such fundamental building blocks of science and innovation should not be privately owned:

The relevant principle of law “[e]xclude[s] from . . . patent protection . . . laws of nature, natural phenomena, and abstract ideas.” This principle finds its roots in both English and American law

The justification for the principle does not lie in any claim that “laws of nature” are obvious, or that their discovery is easy, or that they are not useful. To the contrary, research into such matters may be costly and time consuming; monetary incentives may matter; and the fruits of those incentives and that research may prove of great benefit to the human race. Rather, the reason for the exclusion is that sometimes *too much* patent protection can impede rather than “promote the Progress of Science and useful Arts,” the constitutional objective of patent and copyright protection.¹⁹⁷

Similarly, many scholars have argued that the fundamentality of such natural and scientific discoveries generate concerns regarding the over-breadth of patent rights that would cover such discoveries, which cannot be designed-

ECON. 249, 256–64 (1996) (comparing conditions for minimum and maximum patent length).

195. See, e.g., Timothy Chen Saulsbury, *Pioneers Versus Improvers: Enabling Optimal Patent Claim Scope*, 16 MICH. TELECOMM. & TECH. L. REV. 439, 442 (2010) (“[A] patent system entails an unavoidable tradeoff between incentivizing pioneering inventions and subsequent improvements; though the prospect of a broad patent may provide stronger incentives for creation and commercialization of new developments, its scope reduces incentives for other inventors to improve upon that work.”).

196. *Bilski v. Kappos*, 561 U.S. 593, 601–02 (2010); see, e.g., European Patent Convention, Art. 52(2)(a), Oct. 5, 1973, 1065 U.N.T.S. 254 (“The following in particular shall not be regarded as inventions within the meaning of paragraph 1: (a) discoveries, scientific theories and mathematical methods . . .”).

197. *Laboratory Corp. of Am. Holdings v. Metabolite Labs., Inc.*, 548 U.S. 124, 126 (2004) (Breyer, J., dissenting from dismissal of cert. as improvidently granted) (quoting U.S. CONST. art. I, § 8, cl. 8; *Diamond v. Diehr*, 450 U.S. 175, 185 (1981)) (citing *Dolbear v. American Bell Tel. Co. (The Telephone Cases)*, 126 U.S. 1 (1888); *O’Reilly v. Morse*, 15 How. 62 (1854); *Le Roy v. Tatham*, 14 How. 156, 175 (1852); *Neilson v. Harford*, 151 Eng. Rep. 1266, 1273 (1841)).

around (because that is how the world works), and which would therefore dominate too much sequential innovation.¹⁹⁸

Other scholars, including one of the present authors, have argued that the exclusions from the patent system for fundamental scientific and natural discoveries reflect historic religious and deontological moral views that such basic aspects of the world are not proper subjects of private property rights.¹⁹⁹ Scientific and natural discoveries were not considered to be human but rather divine inventions, and scientists were thought to have religious and moral duties to disseminate their fundamental discoveries freely for the benefit of all (which views later formed the basis for the Mertonian norm of open and communal science).²⁰⁰ As eloquently stated by Lord Camden in 1774, scientists were “entrusted by Providence with the delegated power of imparting to their fellow creatures that instruction which heaven meant for universal benefit; they must not be niggards to the world, or hoard up for themselves

198. See, e.g., Mark A. Lemley et al., *Life After Bilski*, 63 STAN. L. REV. 1315, 1328–29 (2011) (“But what ideas are reserved to society? Those that are fundamental, the building blocks of human thought . . . the abstract ideas exception operates where a patent claim is ‘too broad’ in the sense that it encroaches upon society’s right to unfettered access to scientific truths, fundamental principles, and the like; these properly belong in the commons upon which future innovations can be built, ‘free to all men and reserved exclusively to none.’ This concern about overbreadth is not, we think, limited to the abstract ideas doctrine; it also animates the prohibition against patenting products of nature.”) (quoting *Funk Bros. Seed Co. v. Kalo Inoculant Co.*, 333 U.S. 127, 130 (1948)); see also *id.* at 1335 (“Our scope theory is also largely consistent with the Court’s more recent ‘abstract idea’ decisions In short, whatever was new about the invention [in *Gottschalk v. Benson*, 409 U.S. 63 (1972)] was unmoored to any practical application, such that it was ‘so abstract and sweeping’ as to unduly foreclose follow-on invention, particularly that using after-arising technologies. Given the Court’s concern with ‘unknown uses’ and ‘future-devised machinery,’ *Benson* cannot merely be explained by traditional scope and disclosure doctrines.”) (quoting *Benson*, 409 U.S. at 64–68)).

199. Joshua D. Sarnoff, *Patent-Eligible Inventions After Bilski: History and Theory*, 63 HASTINGS L.J. 53, 121–24 (2011) [hereinafter Sarnoff, *Patent-Eligible Inventions After Bilski*].

200. See, e.g., *id.* at 63–90 (tracing the relevant history in post-Enlightenment philosophical thought, including internal limits to private property within John Locke’s labor-based property theory, religious views of the divine origins of nature and human discovery, and 18th through 20th Century legal standards reflecting these limitations). See generally Robert K. Merton, *The Normative Structure of Science*, in THE SOCIOLOGY OF SCIENCE: THEORETICAL AND EMPIRICAL INVESTIGATIONS 267, (Norman W. Storer ed., U. of Chi. Press 1973) (1945).

the common stock.”²⁰¹ These and similar deontological moral concerns have informed legislative prohibitions of patents on human organisms²⁰² and on human and animal diagnostic and medical treatment methods.²⁰³ Yet other deontological concerns (addressing freedom of thought or freedom from exclusive rights in various domains of life, particularly where patent incentives are thought to be unnecessary) may be at issue in regard to patents on business methods, software, mental acts, games, and the like.²⁰⁴ It should be obvious from this brief discussion that patents on fundamental or emerging technologies will be highly controversial.

Even without regard to concerns about “owning” science and nature, broad fundamental patents raise important problems for sequential innovation. Allocating broad new technological fields to a single patent holder can stifle innovation by others who might be in a better position to improve and advance the technology.²⁰⁵ Patentable improvements to pioneering inventions may block commercial production by requiring licenses from both the pioneering and

201. Speech by Lord Camden (Feb. 21, 1774), in 17 THE PARLIAMENTARY HISTORY OF ENGLAND 999 (T.C. Hansard ed. 1813) (1774).

202. See Leahy-Smith America Invents Act, Pub. L. No. 112–29, § 33, 125 Stat. 284 (2011). See generally Yaniv Heled, *On Patenting Human Organisms or How the Abortion Wars Feed into the Ownership Fallacy*, 36 CARDOZO L. REV. 241, 253 (2014) (discussing the Section 33 and the Weldon Amendment, which affirmed 1987 USPTO policy “restricting funds for issuing patents on human embryos [and] human organisms”).

203. See, e.g., European Patent Convention, *supra* note 196 art. 53(c) (“European patents shall not be granted in respect of... (c) methods for treatment of the human or animal body by surgery or therapy and diagnostic methods practised on the human or animal body . . .”).

204. See, e.g., *id.* art. 52(2)(b)–(d) (“(b) aesthetic creations; (c) schemes, rules and methods for performing mental acts, playing games or doing business, and programs for computers; (d) presentations of information”); *id.* art. 53(a)–(b) (“(a) inventions the commercial exploitation of which would be contrary to ‘ordre public’ or morality . . . (b) plant or animal varieties or essentially biological processes for the production of plants or animals . . .”); Sarnoff, *Patent-Eligible Inventions After Bilski*, *supra* note 199, at 62–63 (“These moral norms include valuing our common heritage, protecting freedom of thought and expressive communication, preserving bodily integrity and personality, and maintaining certain activities or things free from the patent system or subject to certain kinds of equal treatment, as for tax planning methods and human organisms or sporting activities.”). See generally John R. Thomas, *The Patenting of the Liberal Professions*, 40 B.C. L. REV. 1139, 1179 (1999).

205. See, e.g., Brian Love, *Interring the Pioneer Invention Doctrine*, 90 N.C. L. REV. 380, 436–56 (2012) (describing the friction between the pioneering inventor and subsequent improvers).

improvement patent holders.²⁰⁶ Numerous patent law doctrines are intended to prevent patents from claiming technologies that are broader than their actual contribution to the art.²⁰⁷ However, these doctrines do not preclude the issuance of broad patents on pioneering discoveries or on claiming inventions using broad functional language, which may then dominate a wide swath of later-developed technologies.²⁰⁸ As Robert Merges and Richard Nelson have argued, “the granting of broad patents in many cases has stifled technical advance and that where technical advance has been rapid there almost always has been considerable rivalry.”²⁰⁹ Because SCE is an emerging technology in an untested market, the potential for broad functional and preclusive patent claims is a possibility.

As a result of these concerns, a number of scholars have studied alternatives to the patent system that may promote innovation in particular technical areas. These alternative mechanisms include tax credits for desirable R&D activities, funding research priorities through grant awards, and issuing prizes to those who successfully achieve desired technical milestones.²¹⁰ Some of these mechanisms have been used to

206. See, e.g., Merges & Nelson, *supra* note 194, at 860–68.

207. See, e.g., Dennis Crouch & Robert Merges, *Operating Efficiently Post-Bilski by Ordering Patent Doctrine Decision-Making*, 25 BERKELEY TECH. L.J. 1673, 1684–86 (2010).

208. See 35 U.S.C. § 112(a)–(b)&(f) (2012) (enablement and written description, definiteness, and functional claiming doctrines); Jason Rantanen, *Teva, Nautilus, and Change Without Change*, 18 STAN. TECH. L. REV. 538, 548 (2015) (discussing the indefiniteness doctrine for patent claims); Kevin T. Richards, *Experimentation and Patent Validity: Restoring the Supreme Court’s Incandescent Lamp Patent Precedent*, 101 VA. L. REV. 1545, 1554–55 (2015) (discussing the enablement doctrine for patent claims); Mark A. Lemley, *Software Patents and the Return of Functional Claiming*, 2013 WIS. L. REV. 905, 964 (2013) (discussing the need for better limits on use and interpretation of functional claiming language in patents). See generally Jeffrey A. Lefstin, *The Formal Structure of Patent Law and the Limits of Enablement*, 23 BERKELEY TECH. L.J. 1141 (2008).

209. Merges & Nelson, *supra* note 194, at 877.

210. See generally SUZANNE SCOTCHMER, *INNOVATION AND INCENTIVES* 31–58 (2004); MARIANA MAZZUCATO, *THE ENTREPRENEURIAL STATE: DEBUNKING PUBLIC VS. PRIVATE SECTOR MYTHS* 52–54 (Kevin Gallagher et al. eds, Anthem Press 2013); Joshua D. Sarnoff, *Government Choices in Innovation Funding (with Reference to Climate Change)*, 62 EMORY L.J. 1087, 1119 (2013) [hereinafter Sarnoff, *Government Choices*]; NAT. RES. COUNCIL OF THE NAT’L ACADS., *RIISING TO THE CHALLENGE: U.S. INNOVATION POLICY FOR THE GLOBAL ECONOMY* 53–56 (Charles W. Wessner & Alan Wm. Wolff eds., 2012) (discussing government funding and other government sponsored incentives).

achieve governmental technology development goals for some time. Governmental grants to academic institutions and private industry have been used in the United States since World War II to foster the development of technologies ranging from advanced weapons to spacecraft to the majority of biomedical research conducted today.²¹¹ Prizes have an even longer history, and many scholars cite the famous account of the British government's £20,000 prize offered to the developer of the first successful means for determining longitude at sea.²¹² Since then, both governments and private foundations have offered a range of prizes for technological developments.²¹³ Significantly, such measures may be supplied by governments either as alternatives or as additions to patent rights, and where the additional measures may not eliminate concerns over such rights.

B. THE POTENTIAL FOR PATENT THICKETS AND ANTI-COMMONS

When numerous patents exist in a technological field, it is possible for a “thicket” or an “anti-commons” to develop. In such situations, it becomes costly and time-consuming—if not impossible—for other market participants to conduct research and improve upon the patented technology.²¹⁴ This phenomenon has been part of the patent system for a very long

211. See, e.g., Peter Galison, *The Many Faces of Big Science, introduction to BIG SCIENCE: THE GROWTH OF LARGE-SCALE RESEARCH* 1, 3 (Peter Galison & Bruce Hevly, eds., 1992); SCOTCHMER, *supra* note 210, at 16–26; INST. OF MED., *LARGE-SCALE BIOMEDICAL SCIENCE: EXPLORING STRATEGIES FOR FUTURE RESEARCH* 29–79 (Sheryl J. Nass & Bruce W. Stillman, eds., 2003) (offering numerous examples of large-scale government funded projects).

212. See generally DAVA SOBEL, *LONGITUDE: THE TRUE STORY OF A LONE GENIUS WHO SOLVED THE GREATEST SCIENTIFIC PROBLEM OF HIS TIME* (1995) (telling the story of John Harrison and his invention that led to the discovery of longitude); Jonathan R. Siegel, *Law and Longitude*, 84 TUL. L. REV. 1, 3–4 (2009).

213. See, e.g., Fiona Murray et al., *Grand Innovation Prizes: A Theoretical, Normative, and Empirical Evaluation*, 41 RES. POL'Y 1779, 1780–81 (2012); KNOWLEDGE ECOLOGY INT'L, *SELECTED INNOVATION PRIZES AND REWARD PROGRAMS*, (2008), http://keionline.org/misc-docs/research_notes/kei_rn_2008_1.pdf; SCOTCHMER, *supra* note 210, at 8–11.

214. See, e.g., Carl Shapiro, *Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting*, 1 INNOVATION POL'Y & THE ECON. 119, 119–22 (2001); Michael A. Heller & Rebecca S. Eisenberg, *Can Patents Deter Innovation? The Anticommons in Biomedical Research*, 280 SCIENCE 698, 700 (1998); MICHAEL HELLER, *THE GRIDLOCK ECONOMY: HOW TOO MUCH OWNERSHIP WRECKS MARKETS, STOPS INNOVATION, AND COSTS LIVES* 43 (Basic Books 2008).

time, tracing back to the “sewing machine wars” of the nineteenth century²¹⁵ through the development of airplanes in the early twentieth century²¹⁶ to numerous computer and communications technologies in the late twentieth century.²¹⁷ Again, as Merges and Nelson have observed, “[i]n what we have called cumulative technologies, particularly when the product in question was a multicomponent system, broad patents on components led to [R&D] blockages.”²¹⁸

The emergence of an anti-commons was a particular concern in regard to patenting in the newly developing field of biotechnology, in which numerous applicants in the early 1990s sought to patent expressed sequence tags (ESTs), small fragments of genetic material that were useful as probes in identifying genes and other functional DNA sequences.²¹⁹ Numerous patents on ESTs were issued until the practice was halted, among other things, following efforts of the U.S. National Institutes of Health (NIH) to convince the USPTO to deny such patents based on their lack of known utility.²²⁰ The judiciary subsequently upheld the USPTO’s restrictive approach.²²¹

Concerns about blocking sequential innovation and for triggering an anti-commons are particularly high for pioneering new technologies.²²² This heightened concern exists

215. Adam Mossoff, *The Rise and Fall of the First American Patent Thicket: The Sewing Machine War of the 1850s*, 53 ARIZ. L. REV. 165, 166 (2011).

216. See discussion *infra* Subsection V.B.1.

217. See generally Shapiro, *supra* note 214, at 127–44.

218. Merges & Nelson, *supra* note 194, at 908.

219. See, e.g., Linda J. Demaine & Aaron X. Fellmeth, *Reinventing the Double Helix: A Novel and Nonobvious Reconceptualization of the Biotechnology Patent*, 55 STAN. L. REV. 303, 323–29 (2002); Heller & Eisenberg, *supra* note 214, at 699.

220. See 35 U.S.C. § 101 (2012) (authorizing patents for “new and useful” categories of eligible subject matter); see also Jorge L. Contreras, *Bermuda’s Legacy: Policy, Patents, and the Design of the Genome Commons*, 12 MINN. J.L. SCI. & TECH. 61, 83–84 (2011) [hereinafter Contreras, *Bermuda’s Legacy*].

221. See *In re Fisher*, 421 F.3d 1365, 1379 (2005) (“[E]ach of the five claimed ESTs lacks a specific and substantial utility and . . . they are not enabled. Accordingly, the Board’s decision affirming the final rejection of claim 1 of the ‘643 patent for lack of utility under § 101 and lack of enablement under § 112, first paragraph, is affirmed.”).

222. See, e.g., Christopher A. Cotropia & Mark A. Lemley, *Copying in Patent Law*, 87 N.C. L. REV. 1421, 1434–35 (2009); Craig A. Nard, *A Theory of Claim Interpretation*, 14 HARV. J.L. & TECH. 1, 40–41 (2000); Arti K. Rai, *Regulating Scientific Research: Intellectual Property Rights and the Norms of Science*, 94 NW. U. L. REV. 77, 106 (1999).

in part because foundational technological breakthroughs are often essential for subsequent R&D yet difficult or impossible to “design around” (for example, to develop a new technology that does not include some feature of the patented technology), thereby avoiding the broad patent rights of the foundational technology.²²³ For this reason, scholars have raised significant concerns regarding patenting of the foundational and upstream inputs to biotechnology, such as ESTs and other genetic sequences, single nucleotide polymorphisms (SNPs), cell receptors, etc.²²⁴

For example, the early and broad patents on genetic mutations giving rise to significantly elevated risk of breast and ovarian cancer (BRCA1 and BRCA2) have been alleged to have imposed significant delays and social costs on the research, development, and implementation of diagnostic methods for these diseases, arguably impeding both public health and innovation.²²⁵ The company that owned the patents, Myriad Genetics, continues to maintain its dominant position in genetic testing for breast cancer through its trade secret databases of the sequences that it analyzed while excluding competition through its patent rights.²²⁶ These social and innovation costs are particularly salient, given that the genetic sequence patents were later held invalid by the Supreme Court, and the process patents for comparing sequences to determine genetic defects were invalidated by the lower courts.²²⁷ Similarly, recent research has documented how threats and actual litigation against universities and scientists by owners of the patents on certain genes related to

223. See, e.g., Cotropia & Lemley, *supra* note 222, at 1434–35.

224. See Heller & Eisenberg, *supra* note 214, at 699.

225. See, e.g., Robert Cook-Deegan et al., *Impact of Gene Patents and Licensing Practices on Access to Genetic Testing for Inherited Susceptibility to Cancer: Comparing Breast and Ovarian Cancers with Colon Cancers*, 12 GENETICS MED. S15, S15–S16 (2010); Mildred K. Cho et al., *Effects of Patents and Licenses on the Provision of Clinical Genetic Testing Services*, 5 J. MOLECULAR DIAGNOSTICS 3, 3–8 (2003).

226. See, e.g., Robert Cook-Deegan et al., *The Next Controversy in Genetic Testing: Clinical Data as Trade Secrets?*, 21 EUR. J. HUM. GENETICS 585, 585–86 (2013).

227. *Ass’n for Molecular Pathology v. Myriad Genetics*, 133 S. Ct. 2107, 2116–19 (2013); *Ass’n for Molecular Pathology v. U.S. Patent & Trademark Office*, 689 F.3d 1303, 1333–35 (Fed. Cir. 2012). The lower courts also held the probe and primer and methods of screening claims to be invalid. *In re BRCA1- and BRCA2-Based Hereditary Cancer Test Patent Litig.*, 774 F.3d 755, 759–66 (Fed. Cir. 2014).

Alzheimer's disease delayed scientific discovery and impeded public health.²²⁸

Scholars have also raised concerns regarding the potential for patents at an early stage to retard the development and deployment of nanotechnology inventions.²²⁹ Patenting levels on basic nanotechnology research and early technological developments have been significant, notwithstanding the fact that the government largely funded these developments in order to stimulate basic research.²³⁰ Accordingly, the patents that have so far been issued—many of them to universities because of the Bayh-Dole Act²³¹—pose significant concerns precisely because they cover fundamental and upstream discoveries and technologies:

The lack of current commercial value notwithstanding, however, much of basic nanotechnology research is protected under patent. In fact, very few of the nanotechnology inventions created thus far ha[ve] not been patented . . .

. . .

. . . [N]anotechnology's cross-disciplinarity multiplies its potential applications, giving patents in nanotechnology unusually

228. See Tania Bubela et al., *The Mouse that Trolled: The Long and Tortuous History of a Gene Mutation Patent That Became an Expensive Impediment to Alzheimer's Research*, 2 J.L. & BIOSCI. 213, 231–32 (2015). Cf. Jon F. Merz, et al., Commentary, *Diagnostic Testing Fails the Test: The Pitfalls of Patents Are Illustrated by the Case of Haemochromatosis*, 415 NATURE 577, 577 (2002) (discussing similar concerns in regard to haemochromatosis patents). It is notable that representative of the patent holders publicly (but falsely) denied threatening researchers with litigation. See Bubela et al., *supra*, at 232. To the extent that much scientific research is conducted through either intentional or unwitting infringement, the lack of forbearance reflected by such actions significantly threatens the research enterprise, absent restoration of a meaningful “experimental use exception” as a limit of the scope of the patent infringement right. See Joshua D. Sarnoff, *The Patent Law Duchy of Grand Fenwick: A Comment on The Mouse that Trolled: The Long and Tortuous History of a Gene Mutation Patent That Became an Expensive Impediment to Alzheimer's Research*, 2 J.L. & BIOSCI. 723, 726–27 (2015).

229. See Mark A. Lemley, *Patenting Nanotechnology*, 58 STAN. L. REV. 601, 618–20 (2005). *But cf.* Emily M. Morris, *The Irrelevance of Nanotechnology Patents* 1–2 (Dec. 29, 2015) (unpublished draft) (on file with the Connecticut Law Review), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2708833 (last visited Nov. 18, 2016) (arguing that to date other constraints such as “technological and economic uncertainty . . . tacit knowledge, lack of funding, and even regulatory and safety issues” have retarded nanotechnology far more than patent rights, while not dismissing the potential for patent rights in the future to generate an anti-commons or otherwise interfere with nanotechnology development).

230. See Lemley, *supra* note 229, at 603; Morris, *supra* note 229, at 5.

231. See Morris, *supra* note 229, at 6.

broad effects in many different areas of development. Those who work in downstream nanotech development may need to negotiate licensing from patent holders outside of their own fields and often may be caught infringing patents from fields well outside of what they might reasonably have been expected to review.²³²

Similarly, producing multi-component products may require the licensing of numerous patented inputs.²³³ This is common in many information and communications technologies that rely on interoperability standards²³⁴ and for multi-input technologies that may include products in fields as diverse as synthetic biotechnology, nanotechnology, and sustainable building materials.²³⁵ Broad patenting has also raised concerns over development of an anti-commons and over interference with development or implementation of multi-component standards.²³⁶ As a result, any given patent may block competitors from producing such products.²³⁷ Some of the measures discussed below in Part V were developed to address the need for cross-licensing in regard to such standardized or multi-input technologies.²³⁸

Further, the lack of readily accessible prior art in a field can result in improperly broad or otherwise invalid patents on non-novel inventions, as is thought to have happened in the context of software patenting beginning in the 1990s.²³⁹ More recently, concerns have arisen that patents on software and business methods in the United States have encouraged the emergence of patent assertion entities (PAEs) whose principle business model is to assert patents of questionable validity so as to obtain nuisance-value settlements (so-called “patent trolling”).²⁴⁰ Of course, most countries have historically been

232. *Id.* at 5, 10.

233. *See, e.g.*, NATL. RES. COUNCIL OF THE NAT. ACADS., PATENT CHALLENGES FOR STANDARD-SETTING IN THE GLOBAL ECONOMY: LESSONS FROM INFORMATION AND COMMUNICATION TECHNOLOGY 15–17 (Keith Maskus & Stephen A. Merrill eds., 2013).

234. *See, e.g., id.*

235. *See, e.g., id.* at 17–19.

236. *See, e.g.*, David S. Evans & Anne Layne-Farrar, *Software Patents and Open Source: The Battle Over Intellectual Property Rights*, 9 VA. J.L. & TECH. 1, 12–18 (2004).

237. *Id.*

238. *See* discussion *infra* Parts V.A.3, V.A.4, V.B.1 & V.B.2.

239. *See, e.g.*, Evans & Layne-Farrar, *supra* note 236, at 11–15 (discussing “bad patents” and the flaws in the patent process).

240. *See, e.g.*, Mark A. Lemley & A. Douglas Melamed, *Missing the Forest for the Trolls*, 113 COLUM. L. REV. 2117, 2126–28 (2013) (discussing problems of aggregation that are not unique to PAEs); Sean P. Miller, *Patent “Trolls”*:

more reluctant than the United States to issue software and (particularly) business method patents.²⁴¹ Because such litigation behaviors have been developing more slowly outside the United States,²⁴² the scope of these problems varies by jurisdiction.

C. RELATIONSHIP TO TRADE SECRETS

It is possible that private entities will acquire specialized knowledge in effectively constructing, deploying, and operating some future SCE technologies. Trade secrets, rather than patents, are more likely to protect these commercial advantages, particularly as they are unlikely to be readily reverse engineered.²⁴³ For example, in an analysis of “clean energy” solar photovoltaic, biofuel, and wind technologies, John Barton concluded that patents in those areas mostly focused on narrow improvements.²⁴⁴ Accordingly, in such areas trade secrecy was more likely than patent rights to be a significant constraint on technology research, development, and

Rent Seeking Parasites or Innovation-Facilitating Middlemen (Apr. 26, 2010) (unpublished Ph.D. dissertation, Stanford University) (on file with the Stanford University library system), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1885538 (last visited Nov. 18, 2016) (finding that PAEs tend to assert patents of higher validity than practicing entities). *But see* Christopher A. Cotropia, Jay P. Kesan & David L. Schwartz, *Unpacking Patent Assertion Entities (PAEs)*, 99 MINN. L. REV. 649, 649–53, 699–70 (2014) (concluding that PAEs and their lawsuits may be considered a sign of health of the U.S. patent system).

241. *See, e.g.*, Evans & Layne-Farrar, *supra* note 236, at 5–8, 12.

242. *See generally* Brian J. Love, et al., *Patent Assertion Entities in Europe*, in *PATENT ASSERTION ENTITIES AND COMPETITION POLICY* (D. Daniel Sokol ed., forthcoming 2017).

243. *See* Strandburg, *supra* note 190, at 113–14 (“[T]he trade-secret return increases because it is reasonable to assume that, without the aid of the patent disclosure, third parties will take relatively longer to come up with follow-on inventions when there is a larger return to trade secret protection, indicating that the invention is more difficult to reverse engineer or invent independently.”).

244. This was in part because broad patents had expired. *See* Barton, *supra* note 124, at 18 tbl.3; *see also* JOHN H. BARTON, *MITIGATING CLIMATE CHANGE THROUGH TECHNOLOGY TRANSFER: ADDRESSING THE NEEDS OF DEVELOPING COUNTRIES*, (2008), <https://www.chathamhouse.org/sites/files/chathamhouse/public/Research/Energy,%20Environment%20and%20Development/1008barton.pdf>; Charles R. McManis & Jorge L. Contreras, *Compulsory Licensing of Intellectual Property: A Viable Policy Lever for Promoting Access to Critical Technologies?*, in *TRIPS AND DEVELOPING COUNTRIES—TOWARDS A NEW WORLD ORDER?* 109, 129 (Gustavo Ghidini et al. eds., 2014).

deployment.²⁴⁵ Similarly, in the context of advanced building materials, producers have been slow to seek patents, relying primarily on trade secrecy and a variety of other commercial strategies to obtain and maintain market share.²⁴⁶ To the extent that significant patenting of broad or upstream technologies is avoided in SCE, concerns over trade secrecy will be correspondingly greater.

Further, trade secrets in SCE technologies may result in significant differences in the structure or operation of systems across vendors or jurisdictions. This may become problematic if the technologies or methods of using them would need to be interoperable to achieve optimal results, cost effectiveness or safe operation.²⁴⁷

Trade secret owners, moreover, could be unwilling to share their skill and knowledge freely to enable the broad, rapid, and responsible diffusion of SCE technologies. It is much more difficult for a government procurement agency to compel sharing of trade secret knowledge—particularly if it is not codified but rather must be disclosed by individuals who possess that knowledge—than to compel the licensing of patents or other IP.²⁴⁸ To the extent that the disclosure of such trade secrets are not made up-front conditions of governmental contracts, the forcible public disclosure of the trade secrets would destroy their secrecy and thus might potentially be considered a “taking,” “condemnation,” or “expropriation” of property that would require compensating the trade secret owner or would provide it with a claim under international trade laws.²⁴⁹ Obviously, significant concerns (as well as

245. See, e.g., Strandburg, *supra* note 190, at 113–14 (discussing how the secrecy aspect of trade secrets likely causes third parties to take longer to develop “follow-on inventions”).

246. See Jorge L. Contreras & Charles R. McManis, *Intellectual Property Landscape of Material Sustainability Standards*, 14 COLUM. SCI. & TECH. L. REV. 485, 502, 507 (2013).

247. Although some variation in the application to local conditions is likely to be necessary, it is unlikely that the use or effects of SCE technologies can be restricted to those jurisdictions.

248. See Elizabeth A. Rowe, *Striking a Balance: When Should Trade-Secret Law Shield Disclosures to the Government?*, 96 IOWA L. REV. 791, 800–03 (2011). See generally *Ruckelshaus v. Monsanto Co.*, 467 U.S. 986 (1984) (discussing whether disclosures of trade secrets to the EPA are protected by the Fifth Amendment’s taking clause).

249. See Rowe, *supra* note 248, at 800–03; *Ruckelshaus v. Monsanto Co.*, 467 U.S. at 986.

substantial liability) might result from the need to disseminate such knowledge broadly.

D. PATENTS ACROSS BORDERS

Patents are, by their nature, limited in scope to the jurisdiction that issues them.²⁵⁰ In contrast, SCE technologies and effects are unlikely to respect international borders. Depending on how patents claim those technologies, difficult questions will likely arise as to whether the use of a technology in one jurisdiction would infringe a patent in another jurisdiction. For example, if a patent claims a new substance that has high reflectivity and thus can be used for SCE, would its release in the atmosphere in one jurisdiction trigger patent infringement in a jurisdiction to which that product inadvertently (but inevitably) migrates? Similar concerns have been raised concerning patent infringement by farmers growing genetically engineered grain resulting from contamination of their crops caused by windborne seed drift.²⁵¹ Another question is the degree to which a patented SCE process would be infringed when acts performed in one jurisdiction necessarily cause some element of a claim to be performed in another jurisdiction. Such concerns have been raised in regard to so-called “divided infringement,” in which some of the steps of a method have been performed outside of the patent-issuing jurisdiction specifically to avoid infringement, but the benefits of performing the method are obtained within the jurisdiction.²⁵² These are concerns that could potentially be addressed through multilateral treaty agreements, though no significant progress in this area has been made to date.

250. See Sean Cunningham & Ronald Yin, *Filing and Defending Patents in Different Jurisdictions*, IPHANDBOOK.ORG, <http://www.iphandbook.org/handbook/ch10/p08/> (last visited Nov. 19, 2016).

251. See, e.g., *Monsanto Canada Inc. v. Shmeiser*, [2004] S.C.R. 902 (Can.) (concerning windborne seed drift).

252. See 35 U.S.C. § 271(g) (2012) (prohibiting importation into the United States of products made abroad using a process patented in the United States). See generally *Eolas Tech. Inc. v. Microsoft Corp.*, 399 F.3d 1325 (Fed. Cir. 2005) (discussing the application of patent law when software code was sent outside the United States); *NTP, Inc. v. Res. in Motion, Ltd.*, 418 F.3d 1282 (Fed. Cir. 2005) (assessing whether patent law applies to systems and methods used in part outside of the United States).

E. PATENT HOLDERS INFLUENCING POLICY

Among the concerns frequently cited in the literature concerning SCE is that SCE research, if funded at a sufficient scale, could catalyze the growth of private interests in these technologies.²⁵³ The potential for broad patent rights would then further attract such interests, but potentially could hinder socially optimal technological development.²⁵⁴ Such rent-seeking interests might then influence decision-makers so that SCE would be researched more vigorously; implemented sooner, at a larger scale, or in a particular manner; or weakly regulated. Some of the resulting policies might be beneficial; others might be socially suboptimal.²⁵⁵ Jane C. S. Long and Dane Scott outline potential incentives for SCE researchers to influence policy.²⁵⁶ Among their recommended policy responses is that “publicly funded research should not lead to patenting that would produce financial vested interests.”²⁵⁷ Of course, concerns about money and power influencing public policy (including research funding and technological developments) is neither new nor limited to SCE.²⁵⁸

In fact, worries about scientists’ patents and self-interested control over research pathways have already affected the course of SCE research. In 2010, the project “Stratospheric Particle Injection for Climate Engineering” (SPICE) began, supported by the U.K. public funding bodies and carried out at

253. See, e.g., Marion Hourdequin, *Geoengineering, Solidarity, and Moral Risk*, in *ENGINEERING THE CLIMATE: THE ETHICS OF SOLAR RADIATION MANAGEMENT* 15, 27 (Christopher J. Preston ed., 2012) (claiming that interests “may create momentum to implement SRM strategies despite the risks or before just decision-making procedures are established”).

254. See generally Gordon Tullock, *Efficient Rent Seeking*, in *TOWARD A THEORY OF THE RENT-SEEKING SOCIETY* 97 (James Buchanan et al. eds., 1980).

255. This is part of a more general concern, often called the “slippery slope,” that some writers express. In this, SCE research makes its implementation more likely, perhaps unduly so.

256. Jane C. S. Long & Dane Scott, *Vested Interests and Geoengineering Research*, 29 *ISSUES SCI. & TECH.* 45, 48 (2013) (discussing proper use of the “four F’s,” fortune, fame, fear, and fanaticism, in incentivising proper geoenvironmental research and avoiding manipulation of the process, which would occur in part due to a misapplication of the four F’s); see also Gareth Davies, *Privatisation and De-Globalisation of the Climate*, 7 *CARBON & CLIMATE L. REV.* 187, 189 (2013).

257. Long & Scott, *supra* note 256, at 50.

258. See, e.g., Joshua D. Sarnoff, *The Likely Mismatch Between Federal Research & Development Funding and Desired Innovation*, 18 *VAND. J. ENT. & TECH. L.* 363, 368 (2016).

Bristol, Cambridge, Edinburgh, and Oxford universities.²⁵⁹ One part of SPICE was to be a field test of delivery equipment for stratospheric aerosol injection.²⁶⁰ In this test, seawater would be pumped up a one-kilometer hose that would be held aloft by a balloon.²⁶¹ Because this would have been the first outdoor SCE test, SPICE's funders and lead investigators agreed to a staged process, in which the decision whether to proceed further would be evaluated during the research project.²⁶² It later came to light that one of the investigators and a person involved in the funding process were listed as inventors on a relevant patent application.²⁶³ This was one of the reasons that the project's leaders canceled the outdoor test.²⁶⁴

F. TECHNOLOGICAL LOCK-IN

Some commentators are concerned that technological (as well as broader, social) lock-in may shape the future course of SCE research and possible implementation.²⁶⁵ In this scenario, an existing solution or technical pathway becomes entrenched due to causes unrelated to its technical merit or economic viability.²⁶⁶ Subsequent, superior innovations are then not adopted, or adopted to a suboptimal degree.²⁶⁷ Economists and historians of science and technology have observed that early decisions regarding technological design, implementation, and dissemination strongly influence future decision-making.²⁶⁸ A handful of economic and other incentives or effects can cause

259. Cressey, *supra* note 55; see also *Spice Project Update*, ENGINEERING AND PHYSICAL SCIENCES RESEARCH COUNCILS (May 22, 2012), <https://www.epsrc.ac.uk/newsevents/news/spiceprojectupdate/>.

260. *Spice Project Update*, *supra* note 259.

261. Cressey, *supra* note 55.

262. See *Spice Project Update*, *supra* note 259 (mentioning the stage gate).

263. Cressey, *supra* note 55.

264. Matt Watson, *Testbed News*, THE RELUCTANT GEOENGINEER (May 16, 2012, 12:03 AM), <http://thereluctantgeoengineer.blogspot.nl/2012/05/testbed-news.html>.

265. See Rose C. Cairns, *Climate Geoengineering: Issues of Path-dependence and Socio-technical Lock-in*, 5 WIREs CLIMATE CHANGE 649, 649–50 (2014); Albert C. Lin, *The Missing Pieces of Geoengineering Research Governance*, 100 MINN. L. REV. 2509, 2513 (2016).

266. See Stan J. Liebowitz & Stephen E. Margolis, *Path Dependence, Lock-in and History*, 11 J.L. ECON. & ORG. 205 (1995).

267. See *id.*

268. See Paul A. David, *Path Dependence: A Foundational Concept for Historical Social Science*, in LAW, ECONOMICS AND EVOLUTIONARY THEORY 88, 101 (Peer Zumbansen & Graf-Peter Calliess eds., 2010).

technological lock-in, such as: economies of scale of production or adoption; learning effects; socially shared expectations; barriers to entry; and network effects.²⁶⁹ Social, political, and cultural conditions can reinforce lock-in.²⁷⁰ As consequences of this path dependency, an inferior technology may become dominant and superior ones may fail to develop or acquire market share.²⁷¹ Scholars assert that lock-in has occurred in a diverse range of industries and markets ranging from typewriter keyboards²⁷² and railroads²⁷³ to nuclear reactors²⁷⁴ and fossil fuels.²⁷⁵ However, others contest the empirical evidence of technological lock-in in certain industries.²⁷⁶

IP policy might be able to influence the probability and severity of lock-in. Clearly, broad foundational patents that are difficult to work around may cause future R&D to rely suboptimally upon certain technologies within the scope of the broad patent that the patent holder controls or directs. At the same time, nontraditional IP arrangements that are intended to avoid common shortcomings can have similar effects.²⁷⁷ For example, a patent pool could be so convenient and offer such reduced transaction costs that alternative avenues of research may go underexplored.²⁷⁸

269. See generally Michael L. Katz & Carl Shapiro, *Network Externalities, Competition, and Compatibility*, 75 AM. ECON. REV. 424 (1985) (reviewing the theoretic bases of lock-in).

270. See Andy Stirling, “Opening Up” and “Closing Down”: Power, Participation, and Pluralism in the Social Appraisal of Technology, 33 SCI. TECH. & HUM. VALUES 262 (2008) (proposing how social forces can influence technologies’ paths).

271. *Id.* (“Lock-in often results not from obvious technical superiority but rather from processes of path-dependence.”).

272. Paul A. David, *Clio and the Economics of QWERTY*, 75 AM. ECON. REV. 332, 334 (1985).

273. Douglas J. Puffert, *The Standardization of Track Gauge on North American Railways, 1830-1890*, 60 J. ECON. HIST. 933, 938–39 (2000).

274. Robin Cowan, *Nuclear Power Reactors: A Study in Technological Lock-in*, 50 J. ECON. HIST. 541, 541 (1990).

275. Gregory C. Unruh, *Understanding Carbon Lock-in*, 28 ENERGY POL’Y 817, 817–18 (2000).

276. See Stan J. Liebowitz & Stephen E. Margolis, *The Troubled Path of the Lock-in Movement*, 9 J. COMPETITION L. & ECON. 125 (2013) (challenging “the empirical support for [lock-in] theories and their real-world applicability”).

277. See, e.g., Subsection VI.A.3 *infra*.

278. It is for this reason that antitrust authorities have typically frowned upon the formation of patent pools that include technologies that are substitutes for one another. See Subsection VI.A.3 *infra*.

G. PATENTABLE SUBJECT MATTER

A common, deep critique of SCE is that it would represent a magnitude and category of intervention in the natural world that is or should be beyond humanity's reach.²⁷⁹ Such arguments appear frequently both outside of academic scholarship and in public opinion surveys, focus groups, and the popular press.²⁸⁰ Environmental advocates are among those who claim that SCE would be "playing God." For example, Green activist Clive Hamilton asserts that

there are certain qualities that humans cannot and should not aspire to, both because they are beyond us and because aspiring to them invites calamity Playing God entails humans crossing a boundary to a domain of control or causation that is beyond their rightful place. In this view, there is a limit to what humans should attempt or aspire to because the division between domains is part of the proper order of things.²⁸¹

As SCE's visibility increases, such accusations may also take on more explicitly religious framings.²⁸²

279. See e.g., Wylie Carr et al., *Public Concerns about the Ethics of Solar Radiation Management*, in *ENGINEERING THE CLIMATE: THE ETHICS OF SOLAR RADIATION MGMT.* 169, 175–177 (Christopher J. Preston ed., 2012); Kate Elizabeth Porter & Mike Hulme, *The Emergence of the Geoengineering Debate in the UK Print Media: A Frame Analysis*, 179 *GEOGRAPHICAL J.*, 342, 349 (2013); Victoria Wibeck et al., *Questioning the Technological Fix to Climate Change: Lay Sense-Making of Geoengineering in Sweden*, 7 *ENERGY RES. & SOC. SCI.* 23, 26 (2015).

280. See, e.g., Dale Jamieson, *Ethics and Intentional Climate Change*, 33 *CLIMATIC CHANGE* 323, 325 (1996); James R. Fleming, *The Climate Engineers*, 31 *WILSON Q.* 46, 49 (2007); Stephen M. Gardiner, *Is "Arming the Future" with Geoengineering Really the Lesser Evil?: Some Doubts about the Ethics of Intentionally Manipulating the Climate System*, in *CLIMATE ETHICS: ESSENTIAL READINGS* 284, 303 (Stephen M. Gardiner et al. eds., 2010); Karen N. Scott, *Engineering the 'Mis-Anthropocene': International Law, Ethics and Geoengineering*, 29 *OCEAN Y.B.* 61, 63 (2015); KIRSTEN MEYER & CHRISTIAN UHLE, *INTEGRATIVE RESEARCH INST. ON TRANSFORMATIONS OF HUMAN-ENV'T SYS.*, *GEOENGINEERING AND THE ACCUSATION OF HUBRIS* (2015), <https://www.iri-thesys.org/discussion-papers/paper-pdfs/discussion-paper-2015-3-final.pdf>.

281. CLIVE HAMILTON, *EARTHMASTERS: PLAYING GOD WITH THE CLIMATE* 178 (2013); see also Press Release, ETC Group, *Announcing the Launch of GeoengineeringMonitor.org* (Feb. 9, 2015), <http://www.etcgroup.org/content/announcing-launch-geoengineeringmonitororg> (last visited Nov. 20, 2016).

282. See, e.g., Forrest Clingerman, *Geoengineering, Theology, and the Meaning of Being Human*, 49 *ZYGON* 6, 6 (2014); Wylie Carr, *This is God's Stuff We're Messing With*, in *GEOENGINEERING OUR CLIMATE*, *supra* note 82; Bronislaw Szerszynski, *Geoengineering and Religion: A History in Four Characters*, in *GEOENGINEERING OUR CLIMATE*, *supra* note 82.

This line of argument is reminiscent of previous societal debates concerning new technologies, particular those involving human genetics and reproduction.²⁸³ As with those techniques, opponents may make the case that SCE inventions should not be eligible for private control through patent rights, based on moral and ethical grounds. Indeed, as discussed above, the laws of most countries have excluded some categories of discoveries and inventions from patentability for reasons of deontological morality.²⁸⁴ Such exclusions are permissible under international IP treaties²⁸⁵ and (as discussed further below in Section VI.B) current U.S. and European Union laws to some extent may already restrict or would authorize further restriction on SCE patenting. A related, but rarely made, critique is that scientists' moral duties should preclude them from seeking to maintain their discoveries as trade (or other) secrets. It remains premature to suggest whether certain proposed SCE technologies, if any, should be ineligible for IP protection beyond existing exclusions for deontological reasons, as further consensus within the social discourse is required in this area.

H. DATA SHARING AND FRAGMENTATION

It is likely that large quantities of observational and experimental data will be generated by research, development, and possible implementation of SCE technologies. Such data may be collected via a variety of means including earth-based systems, seagoing vessels, aircraft, and satellites, and by numerous different governmental and non-governmental organizations. In order to maximize understanding and usage of SCE data, and to provide the greatest amount of information to policy makers weighing the risks and benefits of different SCE approaches, it is critical that such data be shared as broadly and rapidly as possible.

283. See, e.g., PAUL RAMSEY, *FABRICATED MAN: THE ETHICS OF GENETIC CONTROL* (1970) (discussing the moral and religious implications of scientific advancements such as genetic control, cloning, and self-modification).

284. See *supra* notes 200–04 and accompanying text.

285. See Agreement on Trade-Related Aspects of Intellectual Property Rights art. 27, 1994, 33 ILM 1197 [hereinafter TRIPS Agreement]; *infra* note 354 and accompanying text. See generally Jasmine Chambers, *Patent Eligibility of Biotechnical Inventions in the United States, Europe, and Japan: How Much Patent Policy Is Public Policy?*, 34 GEO. WASH. INT'L L. REV. 223 (2002) (discussing the applicability of patent law to biological creations such as microorganism, plant, and human chimeras).

Because of SCE's politically controversial character and capacity for widespread effects, a number of scholars have emphasized the particular importance of transparency of research efforts and results in this area.²⁸⁶ Transparency is normatively desirable in its own right, and instrumentally as a means to inform and engage the public, to improve decision-making, to establish legitimacy, to build trust among actors, to prevent publication bias, to facilitate cooperation among researchers, to make research more efficient, to lower transaction costs, and to help manage risk. Weak transparency results when research data and analysis remain unpublished, are maintained as secrets, are difficult to obtain, or are difficult to understand without the efforts of the primary researchers.²⁸⁷ There are many reasons that may influence researchers to favor weak transparency, including desires of private interests to protect confidential information, those of researchers to suppress negative results, lack of coordination among producers of research data, or simply the high costs to maintain transparency. Neil Craik and Nigel Moore emphasize that transparency is essential in order to reduce SCE's environmental and social risks and to establish and maintain legitimacy.²⁸⁸ For example, the availability and accessibility of relevant data will be necessary for public participation.²⁸⁹ Indeed, all of the suggested principles for SCE have emphasized the necessity of openness and transparency.²⁹⁰

286. See, e.g., John P. Walsh et al., *Effects of Research Tool Patents and Licensing on Biomedical Innovation*, in PATENTS IN THE KNOWLEDGE-BASED ECONOMY 319–22 (Wesley M. Cohen & Stephen A. Merrill eds., 2003); NEIL CRAIK & NIGEL MOORE, CENTRE FOR INTERNATIONAL GOVERNANCE INNOVATION, DISCLOSURE-BASED GOVERNANCE FOR CLIMATE ENGINEERING RESEARCH (2014), <https://www.cigionline.org/publications/disclosure-based-governance-climate-engineering-research>; William C. G. Burns & Jane A. Flegal, *Climate Geoengineering and the Role of Public Deliberation: A Comment on the US National Academy of Sciences' Recommendations on Public Participation*, 5 CLIMATE LAW 252 (2015).

287. See, e.g., Walsh, et al., *supra* note 286, at 319–22 (discussing concerns over delays in publication, sharing of data and materials, etc.).

288. CRAIK & MOORE, *supra* note 286.

289. See generally Burns & Flegal, *supra* note 286.

290. SHEPHERD ET AL., *supra* note 23, at xii; Margaret Leinen, *The Asilomar International Conference on Climate Intervention Technologies: Background and Overview*, 4 STAN. J.L. SCI. & POL'Y 1, 4 (2011), https://journals.law.stanford.edu/sites/default/files/stanford-journal-law-science-policy-sjlspprint/2011/05/leinen_intro_perspective_final.pdf; SOLAR RADIATION MGMT. GOVERNANCE INITIATIVE, SOLAR RADIATION MANAGEMENT: THE GOVERNANCE OF RESEARCH 39 (2011), <https://royalsociety.org/~media>

The customary means of disseminating results in the sciences is through publication in peer-reviewed scientific journals. The results and data reported in journal articles, however, must be distinguished from the much larger quantity of experimental and observational data generated in the course of research and upon which published results are based. While published data are often essential to support a researcher's analysis, the data reported in a journal article are typically only a small fraction of the "raw" data collected or observed.

Traditionally, a researcher who wished to access or use another's raw data, whether to validate the prior researcher's results or to build upon those results, had to rely on informal requests made by telephone or e-mail.²⁹¹ Such informal requests were typically fulfilled, if at all, subject to workloads, staff availability and other logistical factors.²⁹²

Today, large electronic databases and high-speed computer networks enable the dissemination of scientific data in a

/Royal_Society_Content/policy/projects/solar-radiation-governance/DES2391_SRMGI%20report_web.pdf (last visited Nov. 20, 2016); BIPARTISAN POL'Y CENTER, GEOENGINEERING: A NATIONAL STRATEGIC PLAN FOR RESEARCH ON THE POTENTIAL EFFECTIVENESS, FEASIBILITY, AND CONSEQUENCES OF CLIMATE REMEDIATION TECHNOLOGIES 14 (2011), <http://cdn.bipartisanpolicy.org/wp-content/uploads/sites/default/files/BPC%20Climate%20Remediation%20Final%20Report.pdf> (last visited Nov. 20, 2016); Rayner et al., *supra* note 26, at 503; Anna-Maria Hubert & David Reichwein, *An Exploration of a Code of Conduct for Responsible Scientific Research Involving Geoengineering*, 86–92 (Inst. Advanced Sustainability Stud., Working Paper, 2015), http://www.iass-potsdam.de/sites/default/files/files/code_of_conduct_0.pdf (last visited Nov. 20, 2016).

291. See J.H. Reichman & Paul F. Uhler, *A Contractually Reconstructed Research Commons for Scientific Data in a Highly Protectionist Intellectual Property Environment*, 66 L. & CONTEMP. PROBS. 315, 343–348 (2003) (discussing the characteristics of informal data sharing arrangements between scientists).

292. See *id.* There is a growing body of empirical evidence demonstrating that requests for data sharing among scientists are often ignored or refused. See, e.g., Blumenthal et al., *Withholding Research Results in Academic Life Science: Evidence From a National Survey of Faculty*, 277 J. AM. MED. ASS'N 1224, 1226 tbl.1 (2007) (reporting that 8.9% of academic life scientists have refused to share research results with other scientists within the past three years); Blumenthal et al., *Data Withholding in Genetics and the Other Life Sciences: Prevalences and Predictors*, 81 ACAD. MED. 137 (2006) (concluding, on the basis of similar data to that presented in the authors' 2002 paper, that "data withholding is common in biomedical science"); Eric G. Campbell et al., *Data Withholding in Academic Genetics: Evidence from a National Survey*, 287 J. AM. MED. ASS'N 473, 477 (2002) (reporting that 47% of geneticists who requested information relating to published research were denied at least once in the preceding three years, and 10% of all post-publication data results were denied).

systematic and global manner. Initially developed by government laboratories and agencies such as the U.S. Geological Survey, National Aeronautics and Space Administration (NASA), and National Oceanic and Atmospheric Administration (NOAA),²⁹³ these aggregations of public scientific data, sometimes referred to as “science commons” or “research commons,” have become vital resources for the international scientific community. More recently, research commons have come to include data generated by academic or research institutions funded in whole or in part by government grants.²⁹⁴ In a typical arrangement of this nature, a government agency will fund these research centers to procure equipment and generate data in a coordinated or collaborative manner, either in fulfillment of a broader governmental program or as part of a research proposal made by the requesting institution.²⁹⁵ The resulting data are then deposited in a government-operated database such as GenBank, operated by the National Library of Medicine, and is made accessible to other researchers around the world. The existence of these research commons enables the efficient, rapid, and cost-effective sharing of new knowledge and enables study and analysis that otherwise might have been impossible. It is likely that such a global data sharing infrastructure would benefit SCE research, which is inherently transboundary and international.

Despite the potential benefits from large-scale scientific data sharing, obstacles to sharing exist. Industry-sponsored research is often subject to written confidentiality agreements or trade secret restrictions that explicitly prevent researchers from sharing resulting data and methods with others and, in some cases, delaying or even prohibiting the publication of

293. See, e.g., NAT'L RESEARCH COUNCIL ET AL., BITS OF POWER: ISSUES IN GLOBAL ACCESS TO SCIENTIFIC DATA 150–53 box 5.4 (1997); *National Centers for Environmental Information*, NOAA.GOV, <http://www.ncdc.noaa.gov> (formally National Climatic Data Center (NCDC)); BRIT. ATMOSPHERIC DATA CTR., <http://badc.nerc.ac.uk> (discussed in PHILIP LORD ET AL., BIOTECHNOLOGY & BIOLOGICAL SCIS. RESEARCH COUNCIL ET AL., LARGE-SCALE DATA SHARING IN THE LIFE SCIENCES: DATA STANDARDS, INCENTIVES, BARRIERS AND FUNDING MODELS (THE “JOINT DATA STANDARDS STUDY”), app. A-19 (2005), http://www.nesc.ac.uk/technical_papers/UKeS-2006-02.pdf).

294. Paul N. Schofield et al., *Sustaining the Data and Bioresource Commons*, 330 SCIENCE 592, 592 (2010).

295. *Id.*

their results.²⁹⁶ Academic researchers themselves often have strong incentives to keep scientific data confidential, at least until the time of publication, and these incentives are supported, if not mandated, by university policies and procedures.²⁹⁷ Competitive researchers, wishing to gain as much advantage as possible from data collected by their laboratories or groups, may drag their feet before depositing data to public repositories, or make deposits of data that are incomplete or lacking critical interpretive information. IP protection for databases and data, particularly in Europe where such protection is strongest, may also hinder the willingness of researchers, and their institutions, to share data with others.²⁹⁸ In some cases, even data that might otherwise be in the public domain (such as mapping and geographic data developed under contract to the U.S. Federal Government) may be stored in proprietary databases that are accessible only by paid subscribers.²⁹⁹ In several areas, the “privatization” of governmental data is proceeding at a rapid pace due to perceptions of inefficiency and poor quality of governmental databases.³⁰⁰ In other cases, large repositories of scientific data maintained by governmental agencies may be discontinued or turned over to private hands due to the high costs of maintaining them.³⁰¹ Finally, restrictive licensing of patented technologies may provide patent holders with substantial amounts of data that can be maintained as proprietary information and protected by trade secrecy, long after the patent rights expire or the patents are invalidated.³⁰²

296. See NAT'L ACAD. OF SCIS. ET AL., ENSURING THE INTEGRITY, ACCESSIBILITY, AND STEWARDSHIP OF RESEARCH DATA IN THE DIGITAL AGE 67 (2009) [hereinafter NAS INTEGRITY, ACCESSIBILITY, AND STEWARDSHIP]; MARGIE PATLAK ET AL., INST. OF MED. OF THE NAT'L ACADS., EXTENDING THE SPECTRUM OF PRECOMPETITIVE COLLABORATION IN ONCOLOGY RESEARCH: WORKSHOP SUMMARY 36 (2010) (“Competing companies often compel their employees to keep silent about their endeavors, and the sharing of information is often frowned on lest information be divulged that might compromise the company’s competitive advantage”).

297. See PATLAK ET AL., *supra* note 296, at 36–37.

298. See Reichman & Uhler, *supra* note 291, at 355.

299. See NAT'L ACAD. OF SCIS. ET AL., *supra* note 296, at 65 box 3-3.

300. See Reichman & Uhler, *supra* note 291, at 396.

301. See, e.g., Jocelyn Kaiser, *Funding for Key Data Resources in Jeopardy*, 351 SCIENCE 14 (2016) (describing NIH plans to discontinue multiple model organism databases due to high costs of maintenance).

302. See, e.g., Brenda M. Simon & Ted M. Sichelman, *Data Generating Patents*, 111 NW. U. L. REV. (forthcoming 2017), [https:// papers.ssrn.com/sol3/papers.cfm?abstract_id=2753547](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2753547).

Even when researchers wish to share data broadly, legal and technical obstacles often intervene. Significant challenges exist in making data collected by multiple agencies, institutions and private firms interoperable so that they can be accessed, searched, and analyzed in an efficient and effective manner.³⁰³ These difficulties are compounded when data is shared across national boundaries and must comply with a host of different data privacy, protection, and national security regulations.³⁰⁴ In summary, concerns over access to and sharing of data and research results are particularly salient in regard to SCE, given the high stakes involved and the widespread effects SCE R&D may have.

I. MATERIALS TRANSFERS

Finally, it bears noting that scientific researchers have also encountered significant constraints on and delays in obtaining physical research materials, due to other researchers' unwillingness to share such materials and to the cost, time, and complexity of negotiating material transfer agreements (MTAs).³⁰⁵ Restrictive practices relating to physical research materials have been increasing, and may be attributable at least in part to the increased commercial incentives of universities resulting from their patenting activities: "the commercial activities fostered by patent policy do seem to restrict sharing, as do the burden of producing the materials and scientific competition."³⁰⁶ Similar legal and technical obstacles could apply to efforts to share SCE-related research materials internationally, particularly if the materials pose significant health and safety or security risks. To the extent that such materials are genetic resources subject to the CBD, national laws may prevent access to and use of the materials without obtaining "prior informed consent" of the country from

303. See, e.g., Susanna-Assunta Sansone et al, *Toward Interoperable Bioscience Data*, 44 *Nature Genetics* 121 (2012); Jorge L. Contreras & A. James Cuticchia, *Technical Standards and Bioinformatics*, in *BIOINFORMATICS LAW: LEGAL ISSUES FOR COMPUTATIONAL BIOLOGY IN THE POST-GENOME ERA* (Jorge L. Contreras & A. James Cuticchia, eds., 2013).

304. See Jorge L. Contreras & Jerome H. Reichman, *Sharing by Design: Data and Decentralized Commons*, 350 *SCIENCE* 1312, 1314 (2015) (describing issues in terms of "legal interoperability").

305. See, e.g., Walsh et al., *supra* note 286, at 319–22; John P. Walsh et al., *View from the Bench: Patents and Material Transfers*, 309 *SCIENCE* 2002, 2002–03 (2005) [hereinafter Walsh et al. *View from the Bench*].

306. Walsh et al. *View from the Bench*, *supra* note 305, at 2003.

which the materials are accessed.³⁰⁷ Further, any commercial benefits that derive from scientific research with those materials are supposed to be shared “fairly and equitably” and subject to “mutually agreed terms.”³⁰⁸ These concerns with sharing of physical materials, however, are not addressed further, except to note here that our proposal in Section VI.B below for a research commons and IP pledges may help to promote the development of norms to share such materials.

V. EXISTING APPROACHES TO FACILITATE SHARING, DISSEMINATION AND DEPLOYMENT OF INNOVATIONS

In order to facilitate the responsible R&D of SCE technologies on a global scale while evaluating and managing their risks before any decision to implement such technologies may occur, novel governance approaches will be needed. Although the challenges of choosing among various approaches and adopting them will be substantial,³⁰⁹ SCE funders, researchers, developers, and regulators need not start from scratch. In assessing the available governance options and modalities for SCE, it is useful to consider approaches that have successfully been adopted in other fields. In this Part, we describe a range of historical approaches to the governance of IP for complex scientific and technological research efforts. These approaches can broadly be categorized as involving either state action or private ordering (and often a combination of the two). Within each of these broad categories are numerous different approaches. Below we summarize their general parameters, together with examples of their utilization.

A. STATE INTERVENTIONS

IP systems are fundamentally creatures of the state. As such, state-based political, legislative, and administrative processes can modify and adapt their parameters—the protections they offer as well as limitations and exceptions to those protections. The state can intervene in technology development, information distribution, and IP systems at many different levels.³¹⁰ In this Section, we describe the principal

307. CBD, *supra* note 100, arts. 15(1) & 15(5).

308. *Id.* at art. 15(7).

309. *See, e.g.*, Bodansky, *supra* note 23, at 540–49.

310. One of the authors has identified nine distinct roles for the state in the creation and maintenance of scientific research commons: creator, funder, convenor, collaborator, endorser, curator, regulator, enforcer, and consumer.

roles that the state has historically played with respect to patents and data dissemination concerning new and emerging technologies.

1. Legislative Enactments

In most countries, national-level statutes authorize the issuance of patents. In the United States, the Patent Act (35 U.S.C.) was first enacted in 1790 and most recently amended in 2011.³¹¹ It contains numerous provisions responsive to the needs of specific industry sectors. For example, the Bayh-Dole Act of 1980³¹² amended the Patent Act to enable academic institutions and small businesses receiving federal funds for research to patent the inventions that result therefrom. The Physician's Immunity Statute³¹³ amended the Patent Act to immunize most medical practitioners from patent infringement remedies for the performance of infringing medical procedures. The 2011 Leahy-Smith America Invents Act (AIA) amended the Patent Act to limit patents claiming tax strategies and to prohibit patents on human organisms.³¹⁴ Other statutory provisions not contained in or directly amending the Patent Act also limit the ability to seek and enforce patents in specified fields. For example, the Atomic Energy Act of 1954 (AEA) significantly restricts the ability of applicants to obtain and enforce patents covering atomic weapons technology.³¹⁵

Jorge L. Contreras, *Leviathan in the Commons: Biomedical Data and the State*, in GOVERNING MEDICAL RESEARCH COMMONS (Brett Frischmann et al., eds., Cambridge Univ. Press forthcoming 2017). Each of these roles, while often overlapping, possesses unique characteristics and degrees of influence over research outcomes, dissemination, and commercial deployment.

311. See Patent Act of 1790, ch. 7, 1 Stat. 109, 109–12 (1790); Leahy-Smith America Invents Act, Pub. L. No. 112-29, 125 Stat. 284 (2011) (codified as amended in scattered sections of 15 U.S.C., 28 U.S.C., 35 U.S.C.).

312. Patent and Trademark Law Amendments Act, Pub. L. No. 96-517, 94 Stat. 3015, 3019 (1980) (codified at 35 U.S.C. § 200).

313. Omnibus Consolidated Appropriations Act of 1997, Pub. L. No. 104-208, § 616, 110 Stat. 3009, 3009–67 (1996) (codified at 35 U.S.C. § 287(c)).

314. America Invents Act §§ 14, 33.

315. 42 U.S.C. §§ 2181–2190 (2012); see also Stefan A. Riesenfeld, *Patent Protection and Atomic Energy Legislation*, 46 CAL. L. REV. 40, 51–53 (1958). Some refer to the Atomic Energy Act as creating a “*sui generis* patent system” for “the patentability of technology related to nuclear weapons and energy.” Shobita Parthasarathy et al., *A Public Good? Geoengineering and Intellectual Property* 9–10 (Univ. of Mich. Gerald R. Ford Sch. of Pub. Pol’y, Sci., Tech., & Pub. Pol’y Program, STTP Working Paper 10-1, 2010), <http://stpp.fordschool.umich.edu/policy-consultations/GAO%20papers/Item%20B15-A%20Public%20Good,%20GAO%20STPP%20Working%20Paper%2010-1.pdf>. This termin-

Further, the Drug Price Competition and Patent Term Restoration Act (commonly known as the Hatch-Waxman Act)³¹⁶ amended both the Patent Act and the Federal Food, Drug and Cosmetic Act so as to exclude from the definition of patent infringement activities with the patented invention reasonably related to the submission of a request to the U.S. Food & Drug Administration for marketing approval of generic pharmaceuticals and medical devices.³¹⁷

Although one of the basic arguments for the patent system is to provide incentives to develop and disseminate new technologies (as discussed in Part IV above³¹⁸), some commentators have suggested that amendments to existing statutory regimes, particularly to restrict patentability, may better encourage the responsible research, development, and possible implementation of SCE technologies. For example, Parthasarathy et al. and Chavez look to the patent-limiting features of the AEA as models for potentially limiting the patentability of climate engineering technologies.³¹⁹ We address these proposals and other possible restrictions on patentability in Part VI below.³²⁰

In a different vein, states also have the power to regulate commerce and industry within their borders. In most developed countries, the government seeks to protect the environment through regulation of industrial pollution, vehicular emissions, water contamination, and the like. Governments have increasingly turned to environmental regulatory and market-based regulation to mitigate the onset of climate change.³²¹ The

ology is puzzling, as the AEA creates no *sui generis* form of protection, as that term is generally understood, but merely limits the ability of applicants to obtain patents that would claim atomic weapons technology, and imposes various disclosure and ownership transfer provisions relating to such patents. The resulting patents, however, are the same types of patents issued by the USPTO on other forms of technology.

316. Drug Price Competition and Patent Term Restoration Act, Pub. L. No. 98-417, 98 Stat. 1585 (1984) (codified at 21 U.S.C. § 355(j)).

317. See 35 U.S.C. § 271(e)(1) (2012).

318. See *supra* notes 187–308 and accompanying text.

319. See, e.g., Parthasarathy et al., *supra* note 315, at 9–12; Chavez, *supra* note 125, at 18–19.

320. See *infra* notes 453–83 and accompanying text.

321. See, e.g., Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, 80 Fed. Reg. 64,661 (Oct. 23, 2015) (to be codified at 40 C.F.R. pt. 60) (Clean Power Plan for existing fossil-fuel-fired generating units); 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, 77 Fed. Reg. 62623 (Oct. 15, 2012) (codified at 40 C.F.R.

imposition of stricter environmental controls, such as emission limitations and tradable permit systems,³²² and the creation of financial incentives for clean-technology development and usage, such as plug-in electric or hybrid vehicle tax incentives,³²³ as well as government procurement of clean energy technologies,³²⁴ are likely to be increasingly relied on as measures to control carbon and other GHG emissions. This is particularly the case given the ambitious emissions abatement and financing goals contained in the recently signed Paris Agreement.³²⁵ An extensive literature has developed addressing the effects of product and process, information, and market regulation on promoting or restricting technology development.³²⁶ While using such regulatory approaches to promote SCE technology development may prove useful, proscriptive regulations do not directly address the IP governance issues that are the central concern of this article, and thus are not addressed further.

2. Administrative Actions

Administrative actions of government agencies can have a significant effect on incentives and conditions for technology and information development, sharing, and dissemination. For

pt. 85, 86, 600) (regulating vehicle fuel efficiency standards); Directive 2003/87/EC, 2003 OJ (L 275) 32, <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02003L0087-20140430&from=EN> (last visited Feb. 12, 2015).

322. See, e.g., source cited *supra* note 321; Lawrence H. Goulder & Andrew R. Schein, *Carbon Taxes v. Cap and Trade: A Critical Review*, 4 CLIMATE CHANGE ECON. 1350010, at 1 (2013).

323. See, e.g., Jim Motavalli, *China to Subsidize Electric Cars and Hybrids*, N.Y. TIMES (June 2, 2010), <http://wheels.blogs.nytimes.com/2010/06/02/china-to-start-pilot-program-providing-subsidies-for-electric-cars-and-hybrids/>.

324. See, e.g., Directive 2009/33/EC, 2009 O.J. (L 120) 5, <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:120:0005:0012:EN:PDF> (last visited Feb. 12, 2015).

325. See U.N. Framework Convention on Climate Change, *Draft Decision for the Adoption of the Paris Agreement of the Parties on Its Twenty-First Session*, arts. 2.1, 3, 4.3, 9.1, U.N. Doc. FCCC/CP/2015/L.9/Rev.1, Annex (Dec. 12, 2015), <https://unfccc.int/resource/docs/2015/cop21/eng/l09.pdf> (last visited Feb. 12, 2016).

326. See, e.g., Sarnoff, *Government Choices*, *supra* note 210, at 1143–48 (citing, *inter alia*, David Popp et al., *Energy, the Environment, and Technological Change* 4–6 (Nat'l Bureau of Econ. Research, Working Paper No. 14832, 2009); Nicholas A. Ashford et al., *Using Regulation to Change the Market for Innovation*, 9 HARV. ENVTL. L. REV. 419 (1985); Shameek Konar & Mark A. Cohen, *Information as Regulation: The Effect of Community Right to Know Laws on Toxic Emissions*, 32 J. ENVTL. L. ECON. & MGMT. 109 (1997)).

example, prior to the Bayh-Dole Act of 1980, government agencies adopted different policies regarding whether to obtain patents on technologies developed with government funds and license them to industry or to allow the recipients of federal grants, contracts, and other subsidies to obtain patents themselves.³²⁷ This uncoordinated diversity of federal policies is widely believed to have stymied the commercialization of many federally funded technologies.³²⁸

As discussed below, the NIH has had a profound effect on publication of research results and of underlying data, by requiring funding recipients to make all publications based on NIH-funded research publicly available through the National Library of Medicine's PubMed Central database within one year after publication.³²⁹

Of course, agencies also can make a big difference to technology development and market incentives concerning the substantive rules or policies they adopt over IP rights. These actions may include rules or policies regarding grants of such rights (such as the restrictive policy that the USPTO adopted in regard to EST patents, discussed above),³³⁰ fees imposed on acquisition or maintenance of such rights,³³¹ and market regulation or competition law policies affecting use or licensing of IP rights.³³² Agencies can also adopt measures such as administrative subsidies, which may include waiving or lowering fees to acquire such rights or processing applications more quickly.³³³ One notable example was the "Green

327. See, e.g., WENDY H. SCHACHT, CONG. RESEARCH SERV., RL32076, THE BAYH-DOLE ACT: SELECTED ISSUES IN PATENT POLICY AND THE COMMERCIALIZATION OF TECHNOLOGY (2012), <https://fas.org/sgp/crs/misc/RL32076.pdf> (last visited Feb. 12, 2016).

328. See Rebecca S. Eisenberg, *Public Research and Private Development: Patents and Technology Transfer in Government-Sponsored Research*, 82 VA. L. REV. 1663, 1676 (1996); NAT'L RES. COUNCIL OF THE NAT'L ACADS., MANAGING UNIVERSITY INTELLECTUAL PROPERTY IN THE PUBLIC INTEREST 19 (Stephen A. Merrill & Anne-Marie Mazza, eds., 2010).

329. NAT'L INSTS. OF HEALTH, NOT-OD-08-033, REVISED POLICY ON ENHANCING PUBLIC ACCESS TO ARCHIVED PUBLICATIONS RESULTING FROM NIH-FUNDED RESEARCH (2008) [hereinafter NIH REVISED POLICY].

330. See *supra* notes 219–21 and accompanying text.

331. See, e.g., 35 U.S.C. § 41 (2012) (legislatively specified fees and administrative fee setting authority).

332. See, e.g., DOJ & FTC ANTITRUST GUIDELINES, *supra* note 106. See generally Richard Gilbert & Carl Shapiro, *Antitrust Issues in the Licensing of Intellectual Property: The Nine No-No's Meet the Nineties*, 1997 BROOKINGS PAPERS: MICROECONOMICS 283 (1997).

333. See, e.g., Sarnoff, *Government Choices*, *supra* note 210, at 1121–22.

Technology Pilot Program” of the USPTO, which permitted certain applications (including those for GHG reduction technologies) to be “made special” and considered more quickly (presumably to accelerate grants so as to provide greater investment incentives and to move the technology to market more quickly).³³⁴ Although such administrative subsidy measures may have some beneficial effects,³³⁵ they are likely to be much less significant than substantive agency rules and policies and market regulation policies like those noted above.

3. Governmental Use and March-In Rights

In addition to altering legislative or administrative rules pertaining to a particular subject area or industry, state actors may exercise rights under existing statutory regimes in order to address perceived problems or broader social needs.

For example, under 28 U.S.C. § 1498 (which acts as a waiver of sovereign immunity from suit and an assumption of liability for patent infringement),³³⁶ the U.S. Government reserves the right (itself and through its contractors) to use or manufacture any patented article, provided that the government pays “reasonable and entire compensation” to the patent holder.³³⁷ This provision has been invoked numerous times against the federal government in cases relating to military contracting and technology development and use,³³⁸ although it applies to all governmental actions and actors (such as the U.S. Postal Service).³³⁹

334. U.S. PAT. & TRADEMARK OFF., GREEN TECHNOLOGY PILOT PROGRAM—CLOSED, http://www.uspto.gov/patents/init_events/green_tech.jsp (last visited Oct. 7, 2016).

335. See, e.g., ANTOINE DECHEZLEPRÊTRE, INT’L CTR. FOR TRADE & SUSTAINABLE DEV., FAST-TRACKING GREEN PATENT APPLICATIONS: AN EMPIRICAL ANALYSIS vii (Issue Paper No. 37, 2013), <http://ictsd.org/i/publications/154732/> (noting some potential short-term benefits via diffusion of knowledge).

336. See, e.g., *Zoltek Corp. v. United States*, 672 F.3d 1309, 1312 (Fed. Cir. 2012) (citing *Advanced Software Design Corp. v. Fed. Reserve Bank*, 583 F.3d 1371, 1375 (Fed. Cir. 2009)).

337. 28 U.S.C. § 1498(a) (2012). Disputes regarding compensation are adjudicated by the U.S. Court of Federal Claims. *Id.* For a history and critique of this provision, see Joshua I. Miller, *28 U.S.C. § 1498(a) and the Unconstitutional Taking of Patents*, 13 YALE J.L. & TECH. 1, 29–30 (2011).

338. See, e.g., *Honeywell Int’l, Inc. v. United States*, 609 F.3d 1292, 1294, 1296 (Fed. Cir. 2010) (addressing patents on night vision goggles).

339. See, e.g., *Paymaster Techs., Inc. v. United States*, 180 F. App’x 942, 943 (Fed. Cir. 2006) (non-precedential) (addressing patents on forms).

The Bayh-Dole Act also provides that the federal government retains a non-exclusive, paid-up license to practice any federally funded invention anywhere in the world.³⁴⁰ This Act also authorizes the federal government to exercise so-called ‘march-in’ rights under which it may compel a federally-funded researcher to license such inventions to one or more third parties to the extent necessary to achieve practical application, to address health or safety needs, and for other reasons.³⁴¹

Over the years, several petitions have been filed urging the federal government to exercise its march-in rights under the Bayh-Dole Act, primarily in cases involving under-supplied or costly pharmaceutical products.³⁴² Most recently, more than fifty members of Congress called on NIH to issue detailed guidelines to describe when the agency would exercise march-in rights in response to “price gouging” by pharmaceutical firms.³⁴³ In addition, proposals have been made regarding the

340. 35 U.S.C. § 202(c)(4) (2012); 37 C.F.R. § 401.14(b) (2016). The Act rationalized the previously chaotic rules governing federally-sponsored inventions and allowed researchers to obtain patents on inventions arising from government-funded research. Penalties, including forfeiture of rights, could result from an institution’s failure to pursue patent protection for a federally-funded invention. 35 U.S.C. § 202(c)(3) (2012); 37 C.F.R. § 401.14(d) (2016).

341. 35 U.S.C. § 203(a) (2012); 37 C.F.R. §§ 401.6, 401.14(j) (2016).

342. See Joshua D. Sarnoff, *The Patent System and Climate Change*, 16 VA. J.L. & TECH. 301, 354–55, 355 n.303 (2011) [hereinafter Sarnoff, *The Patent System and Climate Change*] (discussing march-in and various petitions); CellPro, Inc., (Nat’l Insts. of Health Aug. 1, 1997), <http://www.ott.nih.gov/sites/default/files/documents/policy/cellpro-marchin.pdf> (determination rejecting the petition by CellPro to obtain a license to four patents that Johns Hopkins University licensed exclusively to Baxter Healthcare); Abbott Laboratories, Inc., (Nat’l Insts. of Health July 29, 2004), <http://www.ott.nih.gov/sites/default/files/documents/policy/March-In-Norvir.pdf> (determination rejecting the petition that NIH exercise march-in rights against Abbott Laboratories, which had received NIH funding to develop the AIDS drug Norvir, after Abbott increased the retail price of the drug by approximately 400 percent); Genzyme Corp., (Nat’l Insts. of Health Dec. 1, 2010), <https://www.ott.nih.gov/sites/default/files/documents/policy/March-In-Fabrazyme.pdf> (determination rejecting the petition for HHS to permit alternative manufacturer to product the drug Fabrazyme when patent holder failed to meet patient demand).

343. Letter from Rep. Lloyd Doggett, U.S. Representative, et al., to Sylvia Mathews Burwell, Sec’y Dep’t Health & Human Servs., and Francis S. Collins, Dir. Nat’l Insts. Health (Mar. 28, 2016), <http://www.sanders.senate.gov/download/congressional-letter-to-nih-and-hhs-regarding-xtandi?inline=file>; see also Kimberly Leonard, *Can the Government Already Control Drug Prices?*, U.S. NEWS & WORLD REP. (Jan. 11, 2016, 3:41 PM), <http://www.usnews.com/news/articles/2016/01/11/congressional-democrats-urge-nih-to-act-on-drug-prices>.

use of federal march-in rights to address potential areas of national importance beyond pharmaceuticals, including climate emissions abatement technology³⁴⁴ and the electrical smart grid.³⁴⁵ To date, however, federal agencies have not taken action in response to these requests or suggestions.

4. Compulsory Licensing

In addition to statutory provisions enabling the government and its contractors to make use of patented technologies, the state may, in some instances, have the power to require a patent holder to license its technology to others (hence the term “compulsory”) or otherwise authorize production or use of the technology.³⁴⁶ Where a statute automatically authorizes a compulsory license, without the need for the government to act further, it is usually referred to as a “statutory” license.³⁴⁷ Although compulsory licenses frequently involve payment of compensation to the patent holder (as determined by the government authority compelling the license), they often do not require such payment when adopted to remedy competition law violations by the patent holder.³⁴⁸

Statutory licenses are common where the transaction costs of seeking multiple licenses would be substantial.³⁴⁹ For example, U.S. copyright law establishes a widely used compulsory licensing structure for the mechanical reproduction of previously recorded musical works, and for various secondary transmissions by cable systems and satellites.³⁵⁰

344. See Sarnoff, *The Patent System and Climate Change*, *supra* note 342, at 354–56.

345. See Jorge L. Contreras, *Standards, Patents and the National Smart Grid*, 32 PACE L. REV. 641, 671 (2012).

346. *Id.* at 672–73.

347. See, e.g., 17 U.S.C. § 122(a)(1) (2012) (stating that secondary transmissions of a television broadcast within a local market are subject to a statutory license subject to some conditions).

348. See Lawrence Schlam, *Compulsory Royalty-Free Licensing as an Antitrust Remedy for Patent Fraud: Law, Policy, and the Patent-Antitrust Interface Revisited*, 7 CORNELL J.L. & PUB. POL’Y 467, 470 n.13 (1998) (listing several cases where compulsory licensing was ordered “to improve the competitive condition of the . . . marketplace”).

349. See generally 1 PAUL GOLDSTEIN, GOLDSTEIN ON COPYRIGHT § 1.14.2 (3d ed. Supp. 2016) (discussing the law & economics considerations behind statutory copyright licensing).

350. See 17 U.S.C. §§ 111, 112, 114, 119, 122. Compulsory license authority is provided for making and distributing phonorecords and for use of certain

Compulsory licensing exists under the patent law as well.³⁵¹ For example, the AEA authorizes the compulsory licensing of patents “[u]seful in the production or utilization of special nuclear material or atomic energy”³⁵² and the Clean Air Act authorizes under certain conditions the compulsory licensing of patents relating to the prevention of air pollution.³⁵³

Compulsory licensing is also allowed under international treaties, most notably the World Trade Organization’s (WTO’s) Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement.³⁵⁴ Compulsory licensing for exports of pharmaceutical products was expressly addressed by the WTO’s Doha Declaration³⁵⁵ and consequent amendment to the TRIPS Agreement.³⁵⁶ While national governments and scholars have invoked these instruments primarily to address access to medicines in the developing world,³⁵⁷ it has been argued that they may have broader applicability to other critical technologies, including those directed at climate change emissions abatement.³⁵⁸

works in connection with non-commercial broadcasting. See 17 U.S.C. §§ 115, 116.

351. *E.g.*, AEA, 42 U.S.C. § 2183(c) (2012).

352. *Id.*

353. Clean Air Act, 42 U.S.C. § 7608 (2012).

354. See TRIPS Agreement, *supra* note 285; Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299.

355. See World Trade Organization, Ministerial Declaration of 14 November 2001, ¶ 6, WT/MIN(01)/DEC/2, 41 I.L.M. 746 (2001), https://www.wto.org/english/thewto_e/minist_e/min01_e/mindecl_trips_e.pdf.

356. See World Trade Organization, *General Council Decision: Implementation of Paragraph 6 of the Doha Declaration on the TRIPS Agreement and Public Health*, WT/L/540, Corr. 1 (Sept. 1, 2003), http://www.wto.org/english/tratop_e/trips_e/implem_para6_e.htm; World Trade Organization, *Amendment of the TRIPS Agreement: Decision of 6 December 2005*, WT/L/641 (Dec. 8, 2005), http://www.wto.org/english/tratop_e/trips_e/wtl641_e.htm.

357. See, *e.g.*, Colleen Chien, *Cheap Drugs at What Price to Innovation: Does the Compulsory Licensing of Pharmaceuticals Hurt Innovation?*, 18 BERKELEY TECH. L.J. 853, 855–56 (2003); J. H. Reichman, *From Free Riders to Fair Followers: Global Competition Under the TRIPS Agreement*, 29 N.Y.U. J. INT’L L. & POLS. 11, 52–53 (1996); Alan O. Sykes, *TRIPS, Pharmaceuticals, Developing Countries, and the Doha “Solution,”* 3 CHI. J. INT’L L. 47, 49, 62 (2002).

358. See Daniel R. Cahoy, *Inverse Enclosure: Abdicating the Green Technology Landscape*, 49 AM. BUS. L.J. 805, 854–55 (2012) (suggesting the possibility of emergency use of compulsory licensing in the context of renewable energy and other green technologies); McManis & Contreras, *supra* note 244; *cf.* Sarnoff, *The Patent System and Climate Change*, *supra* note 342, at 334–35 (suggesting various measures, including retaining government

5. Funding-Based Controls: Access to Data/Literature

In its 2015 budget, the U.S. Federal Government apportioned approximately \$65 billion to non-defense basic and applied research.³⁵⁹ This spending level makes the U.S. Federal Government the largest single funder of scientific research in the world.³⁶⁰ Other national and state governments also spend large sums on R&D activity.³⁶¹

In addition to direct funding of R&D, governments often act as purchasers of goods and services. The U.S. Federal Government, for example, spends substantial sums annually in its procurement capacity on a wide range of goods and services.³⁶² Large procurement expenditures are also made on the state and local levels and include everything from the construction of new roads and schools to the acquisition of computer systems, communications devices, and online content. “History and economic studies indicate that public procurement may be a very significant incentive to technology development.”³⁶³

The procurement power of the state has often been used to advance a broad range of governmental and social goals by conditioning governmental expenditures or by imposing

ownership rights and using march-in, as less controversial means than compulsory licenses to address access restrictions and high prices for climate change technologies).

359. OFFICE OF SCI. & TECH. POLICY, R&D IN THE 2015 BUDGET (REVISED), (May 2014), <https://www.whitehouse.gov/sites/default/files/microsites/ostp/fy2015rdtables.pdf> [hereinafter OSTP 2015 R&D BUDGET].

360. NAT’L SCI. FOUND., SCIENCE AND ENGINEERING INDICATORS 2016 at 4-4 (2016), <https://www.nsf.gov/statistics/2016/nsb20161/uploads/1/nsb20161.pdf> (“Most of U.S. basic research is conducted at universities and colleges and funded by the federal government.”).

361. *World Development Indicators: Science and Technology*, WORLD BANK, <http://wdi.worldbank.org/table/5.13> (last visited Nov. 14, 2016) (showing that worldwide 2.12% of GDP is spent on R&D).

362. See, e.g., *NHE Fact Sheet*, CTRS. FOR MEDICARE & MEDICAID SERVS., <https://www.cms.gov/research-statistics-data-and-systems/statistics-trends-and-reports/nationalhealthexpenddata/nhe-fact-sheet.html> (last visited Jan. 2, 2017) (explaining that in 2014 the United States government spent \$618.7 billion on Medicare alone).

363. Denis Borges Barbosa & Charlene de Avila Plaza, *The Role of Government Procurement in Regard to Development, Dissemination, and Costs of Climate Change Technologies*, in RESEARCH HANDBOOK ON INTELLECTUAL PROPERTY AND CLIMATE CHANGE 317 (Joshua D. Sarnoff ed., Edward Elgar Publ’g 2016).

requirements on the recipients of governmental funds.³⁶⁴ Requirements imposed on funding recipients and contractors are often intended to achieve goals beyond the direct production or delivery of the research, goods, or services putatively covered by the government expenditure. For example, the U.S. General Services Administration (GSA), Department of Housing and Urban Development, and other federal agencies have adopted aggressive policies to make their construction and building projects environmentally sustainable,³⁶⁵ and numerous municipalities and counties have followed suit.³⁶⁶ This policy approach differs from direct governmental regulation in that it applies only to private actors that voluntarily seek or obtain funding from the government.³⁶⁷

One of the areas in which funding-based regulation has been used most successfully relates to public access to scientific publications. In 2008, the NIH implemented regulations requiring that all publications based on NIH-funded research

364. See, e.g., *Rothe Dev. Corp. v. Dep't of Def.*, 545 F.3d 1023, 1026–27 (Fed. Cir. 2008) (finding unconstitutional an evaluation preference set-aside for “small business concerns owned and controlled by ‘socially and economically disadvantaged individuals,’” in bidding for Defense Department procurement, R&D, military construction, and maintenance contracts). See generally MARIANA MAZZUCATO, *THE ENTREPRENEURIAL STATE: DEBUNKING PUBLIC VS. PRIVATE SECTOR MYTHS* 74 (2013) (observing that the modern state can “[use] its procurement, commissioning and regulatory functions to shape markets and drive technological advance”).

365. U.S. Gen. Servs. Admin., *GSA Moves to LEED Gold for All New Federal Buildings and Major Renovations*, GSA.GOV (Oct. 28, 2010), <http://www.gsa.gov/portal/content/197325> (GSA #10691); U.S. DEPT HOUS. & URBAN DEV., *ENHANCING ENERGY EFFICIENCY AND GREEN BUILDING DESIGN IN SECTION 202 AND SECTION 811 PROGRAMS* 33–39 (2011).

366. See, e.g., Timothy Simcoe & Michael W. Toffel, *Government Green Procurement Spillovers: Evidence from Municipal Building Policies in California*, 13–15 (Harv. Bus. Sch. Tech. & Operations Mgt. Unit Working Paper No. 13-030), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2142085 (describing and offering an explanation for the rapid adoption of LEED standards in different municipalities).

367. In addition to governmental programs, several charitable organizations that fund scientific research impose similar requirements. These include the Howard Hughes Medical Institute, the Wellcome Trust, and numerous disease-specific advocacy and support groups. See, e.g., *Research Policies – Sharing Published Materials/Responsibilities of HHMI Authors (SC-300)*, HOWARD HUGHES MED. INST., http://www.hhmi.org/sites/default/files/About/Policies/sc_300.pdf (last visited Dec. 1, 2016); *Wellcome Trust Requirements*, RES. DATA OXFORD, <http://researchdata.ox.ac.uk/funder-requirements/wellcome-trust/> (last visited Dec. 1, 2016) (compiling Wellcome Trust research data expectations).

be deposited in the PubMed Central database, which provides the public with free access.³⁶⁸ In 2013, the White House Office of Science and Technology Policy (OSTP) expanded the scope of this initiative to all Federal agencies having annual research budgets in excess of \$100 million.³⁶⁹ The OSTP directive also instructed these agencies to develop plans to ensure that all data arising from agency-funded research be publicly accessible and searchable “in ways that maximize the impact and accountability of the Federal research investment.”³⁷⁰ Research funding agencies in other countries including the UK, Germany, and Japan have followed suit with similar requirements for public release of scientific literature following publication.

In addition to published scientific literature, many federal agencies including NASA and NOAA have longstanding policies requiring that scientific data generated using federal funds be made available to the public.³⁷¹ In 1998, the Human Genome Project (HGP)—a jointly funded effort of the U.S. NIH and Department of Energy, the UK-based Wellcome Trust and agencies in Japan, Germany, and elsewhere—adopted a policy mandating that all genetic sequence data be made public within twenty-four hours after being generated (which also prevented patents from claiming such sequences).³⁷² And more recently, the 2013 OSTP directive instructed all covered U.S. federal agencies to develop strategies for “improving the public’s ability to locate and access digital data resulting from federally funded scientific research” and to optimize electronic search, archival, and dissemination capabilities for this data.³⁷³

Policies mandating the public release of research data and literature have several possible goals and outcomes. First, many proponents of open access policies argue that publicly

368. NIH REVISED POLICY, *supra* note 329.

369. Memorandum from John P. Holdren, Dir., Office of Sci. & Tech. Policy, to the Heads of Executive Departments and Agencies: Increasing Access to the Results of Federally Funded Scientific Research 2 (Feb. 22, 2013).

370. *Id.* at 3.

371. *See, e.g.*, NAT’L RESEARCH COUNCIL, BITS OF POWER – ISSUES IN GLOBAL ACCESS TO SCIENTIFIC DATA 80–82 (1997); NAS INTEGRITY, ACCESSIBILITY, AND STEWARDSHIP, *supra* note 296, at 104–05 (noting the Government-Industry Data Exchange Program’s tenure, as one example of a long-standing mechanism for sharing research).

372. *See* Contreras, *Bermuda’s Legacy*, *supra* note 220, at 64–66.

373. Holdren, *supra* note 369, at 2.

funded research necessarily should inure to the benefit of the taxpayers and not to private publishers or firms.³⁷⁴ More generally, there is a belief that public access to research data will foster innovation and discovery. In particular, much has been written about the scientific advances that have been enabled by the culture of rapid and widespread sharing of genomic data fostered by the HGP.³⁷⁵

Finally, public data release has an impact on the ability of other researchers to obtain patent protection claiming inventions potentially anticipated by the released data. This effect was well-known to the planners of the HGP, who adopted a *de facto* patent deterrence policy when they chose to mandate rapid public release of genomic data.³⁷⁶ In particular, the Bermuda Principles ensured that HGP data would be made publicly available before data generators could file patent applications covering “inventions” arising from that data, and in a manner that ensured its early availability as prior art against third party patent filings.³⁷⁷ This result, though praised by many, was also criticized by those who believed that NIH’s discouragement of patents contravened the requirements

374. JOHN WILLINSKY, *THE ACCESS PRINCIPLE: THE CASE FOR OPEN ACCESS TO RESEARCH AND SCHOLARSHIP* 1–3 (William Y. Arms ed., 2006).

375. See, e.g., Heidi Williams, *Intellectual Property Rights and Innovation: Evidence from the Human Genome* 1, 10–12, 24, 121 J. POL. ECON. 1 (2013); Francis Collins, Opinion, *Has the Revolution Arrived?*, 464 NATURE 674, 675 (referring to the “radical ethic of immediate data deposit” adopted by the HGP as the current “norm for other community research projects”); Jane Kaye et al., *Data Sharing in Genomics – Re-shaping Scientific Practice*, 10 NATURE REVS. GENETICS 331, 332 box 1 (2009) (“These policies have created a climate in which data sharing has become the default, and [grant] applicants must demonstrate why their data should be exempt from the requirement that it should be deposited for use by other scientists”).

376. See David R. Bentley, *Genomic Sequence Information Should be Released Immediately and Freely in the Public Domain*, 274 SCIENCE 533, 533–34 (1996); JAMES D. WATSON ET AL., *RECOMBINANT DNA: GENES AND GENOMES – A SHORT COURSE* 295 (3d ed. 2005); Contreras, *Bermuda’s Legacy*, *supra* note 220, at 86–88; Rebecca S. Eisenberg, *Patents and Data-Sharing in Public Science*, 15 INDUS. & CORP. CHANGE 1013, 1025–26 (2006) (discussing the creation of “patent-defeating” prior art through the HGP’s data release rules).

377. In jurisdictions such as the European Union and Japan that have so-called “absolute novelty” requirements, an invention may not be patented if it has been publicly disclosed prior to the filing of a patent application. See JOHN GLADSTONE MILLS III ET AL., *PATENT LAW FUNDAMENTALS* §§ 1:36, 2:30 (2d ed. 2004). In the United States, a patent application may be filed with respect to an invention that has been disclosed in a printed publication, but only if the publication occurred less than one year before the filing of the patent application. 35 U.S.C. § 102(b) (2006).

of the Bayh-Dole Act, which expressly encourages the patenting of federally funded inventions for the benefit of the U.S. economy.³⁷⁸ Nevertheless, such a patent deterrence approach developed during the HGP has continued to be adopted in many government-funded basic research projects both in the United States and elsewhere.³⁷⁹ For SCE, it is worth considering whether there are additional factors when determining whether data should be made generally public, including the potential for SCE techniques to be misused.

NIH continued to discourage federal grantees from seeking patents on the basic tools of biomedical research in its 2005 Best Practices for the Licensing of Genomic Inventions.³⁸⁰ In that document, the agency set forth guidance regarding recommended approaches to patenting NIH-funded genomic discoveries:

Intellectual property protection should be sought when it is clear that private sector investment will be necessary to develop and make the invention widely available. By contrast, when significant further research and development investment is not required, such as with many research material and research tool technologies, best practices dictate that *patent protection rarely should be sought*.³⁸¹

The guidance continues to explain that even when patent protection for genomic discoveries is obtained, such inventions should be licensed on a non-exclusive basis “whenever possible” in order to facilitate the broad availability of enabling technologies within the scientific community.³⁸² As such, at least in the field of genomics and biomedical research, NIH has established a set of norms and expectations regarding the limitation of patent encumbrances on federally-funded

378. Bayh-Dole Act of 1980, 35 U.S.C. §§ 200–12 (2012) (“It is the policy and objective of the Congress to use the patent system to promote the utilization of inventions arising from federally supported research or development . . .”); *see also* Arti K. Rai & Rebecca S. Eisenberg, *Bayh-Dole Reform and the Progress of Biomedicine*, 66 LAW & CONTEMP. PROBS. 289, 308 (2003) (“Arguably, NIH has acted outside the scope of its statutory authority . . . at least with respect to patentable inventions . . .”); JAMES SHREEVE, *THE GENOME WAR* 46 (Ballantine Books Trade Paperback ed. 2005) (“Strictly speaking, the policy directly contradicted the Bayh-Dole Act . . .”).

379. *See* Contreras, *Bermuda’s Legacy*, *supra* note 220, at 63–66. *But see* Jorge L. Contreras, *NIH’s Genomic Data Sharing Policy: Timing and Tradeoffs*, 31 TRENDS IN GENETICS 55 (2015) (noting potential recent NIH movement away from former patent deterrent stance).

380. NIH, Best Practices for the Licensing of Genomic Inventions, 70 Fed. Reg. 18,413, 18,415 (Apr. 11, 2005).

381. *Id.* (emphasis added).

382. *Id.*

innovations, at the stage both of patent acquisition and of subsequent commercialization.³⁸³

B. PRIVATE ORDERING SOLUTIONS

In addition to governmental action, numerous approaches for handling patents and research data have emerged through private ordering and market forces. These fall into three primary categories: patent pools, patent pledges, and data commons.

1. Patent Pools

As discussed in Section IV.B above, when multiple entities each hold patents necessary to conduct research in a particular field or to exploit a particular technology, blocking or thicket situations may arise to limit overall innovation and technology development. Patent pools are private arrangements among patent holders that enable the participants each to operate under the others' patents, to manage and administer the pooled patents on a centralized basis, and often to grant licenses of the pooled patents to third parties, with the proceeds split among the pool members according to an agreed formula.³⁸⁴

Because the holders of complementary patents frequently are competitors, antitrust considerations are relevant in the formation of many pools. One of the earliest patent pools challenged on antitrust grounds involved four leading oil companies that combined their patents covering the processes for extracting excess gasoline from crude oil ("cracking").³⁸⁵ The pool was challenged by the government as an anticompetitive agreement among competitors.³⁸⁶ But in *Standard Oil Co. (Indiana) v. United States*,³⁸⁷ the Supreme Court held that "[a]n interchange of patent rights and a division of royalties . . . is frequently necessary if technical advancement is not to be blocked by threatened litigation."³⁸⁸ The Court thus

383. *Id.* at 18413–15.

384. See, e.g., World Intellectual Prop.Org. (WIPO), *Patent Pools and Antitrust – A Comparative Analysis* 3 (Mar. 2014), http://www.wipo.int/export/sites/www/ip-competition/en/studies/patent_pools_report.pdf (last visited Nov. 16, 2016).

385. See *Standard Oil Co. (Ind.) v. United States*, 283 U.S. 163, 165–66 (1931).

386. *Id.*

387. *Id.*

388. *Id.* at 171.

recognized the pro-competitive benefits that could be achieved by eliminating blocking patent positions and thereby enabling greater innovation and technological development.

Patent pools exist today in a variety of “high technology” industries including semiconductors, consumer electronics, computing, and telecommunications.³⁸⁹ Echoing the Supreme Court’s reasoning in *Standard Oil (Indiana)*, the Department of Justice has typically viewed such pools with approval, citing their ability to “create substantial integrative efficiencies by reducing the time and expense of disseminating the patents to interested licensees, clearing blocking positions, and integrating complementary technologies.”³⁹⁰

Despite the commercial success and broad market adoption of patent pools in fields such as consumer electronics and semiconductors, commercial patent pools have not achieved similar levels of success in other industries. Notably, despite frequent calls for the pooling of patents in the biotechnology industry,³⁹¹ such calls have to date resulted in little patent pooling activity among commercial firms.³⁹²

There are several possible explanations for this failure. First, patent pools come at a steep cost, driven largely by antitrust compliance. A patent pool may stifle competition if it contains patents covering substitute technologies (i.e., it is desirable for alternative technologies to compete in the marketplace, which is less likely to occur if potentially

389. See, e.g., Jonathan M. Barnett, *The Anti-Commons Revisited*, 29 HARV. J.L. & TECH. 127, 191–96 app. (2015) (cataloging more than 100 IP pools from 1900 onward); Jonathan M. Barnett, *From Patent Thickets to Patent Networks: The Legal Infrastructure of the Digital Economy*, 55 JURIMETRICS 1 (2014) (surveying information and communication technology pooling and cross-licensing arrangements); Michael Mattioli, *Communities of Innovation*, 106 NW. U. L. REV. 103 (2012); Richard J. Gilbert, *Antitrust for Patent Pools: A Century of Policy Evolution*, 2004 STAN. TECH. L. REV. 3 (2004); CARL SHAPIRO & HAL R. VARIAN, INFORMATION RULES: A STRATEGIC GUIDE TO THE NETWORK ECONOMY 206–24 (1999).

390. U.S. DEP’T OF JUST. & FED. TRADE COMM’N, ANTITRUST ENFORCEMENT AND INTELLECTUAL PROPERTY RIGHTS: PROMOTING INNOVATION AND COMPETITION 71 (2007) [hereinafter ANTITRUST AND IPR], <http://www.ftc.gov/reports/innovation/P040101PromotingInnovationandCompetitionrpt0704.pdf> (last visited Feb. 22, 2016).

391. See, e.g., David B. Resnik, *A Biotechnology Patent Pool: An Idea Whose Time Has Come?* J. PHIL. SCI. & L., Jan. 2003, at 1; Richard C. Atkinson et al., *Public Sector Collaboration for Agricultural IP Management*, 301 SCIENCE 174 (2003); Heller & Eisenberg, *supra* note 214, at 698–99.

392. See, e.g., Mattioli, *supra* note 389, at 114 (listing several such failures).

competing patent owners are compensated when the pool is licensed).³⁹³ Thus, the pool must contain only patents claiming technologies that are complementary, and which do not act as substitutes for one another. For this reason, the parties forming patent pools typically engage in a lengthy and expensive process (usually through external counsel engaged for the purpose) of vetting each patent that is proposed to be included in the pool and confirming its essentiality to the pool.³⁹⁴

Another reason for the limited commercial success of biotechnology and some other patent pools may be the absence of market demand for such pools. In contrast to high-technology industries in which thousands of patents may cover a single product such as a smartphone, many believe that the feared “thicket” of biotechnology patents has not emerged in a way that hinders innovation or product development.³⁹⁵ If not, then firms may lack the motivation to pool their patents together in order to conduct desired R&D.

Though patent pools have not gained significant commercial traction in non-high-technology industries, a number of pooling arrangements organized principally to achieve humanitarian ends have achieved some success. For example “golden rice,” a genetically-engineered Vitamin A-rich rice variant, was developed by researchers in Europe to address issues of malnutrition in the developing world.³⁹⁶ Bio-agro firm Syngenta, another holder of key patents on the technology,

393. See *Summit Tech., Inc.*, 127 F.T.C. 208, 217–24 (1999) (decision and order); *ANTITRUST AND IPR*, *supra* note 390, at 76–78.

394. See, e.g., *Essentiality Report*, DVD6C LICENSING GRP., <http://www.dvd6cla.com/essential.html> (last updated June 10, 2014) (providing detailed “essentiality reports” for each licensed standard).

395. See, e.g., David E. Adelman & Kathryn L. DeAngelis, *Patent Metrics: The Mismeasure of Innovation in the Biotech Patent Debate*, 85 TEX. L. REV. 1677, 1729 (2007); David E. Adelman, *A Fallacy of the Commons in Biotech Patent Policy*, 20 BERKELEY TECH. L.J. 985 (2005) (showing biotechnology patenting is not adversely affecting innovation); Edmund W. Kitch, *Comment on the Tragedy of the Anticommons in Biomedical Research*, in 50 ADVANCES IN GENETICS 271 (2003); Richard A. Epstein & Bruce N. Kuhlik, *Is There a Biomedical Anticommons?*, 27 REGULATION 54 (2004); Chester J. Shiu, Note, *Of Mice and Men: Why an Anticommons Has Not Emerged in the Biotechnology Realm*, 17 TEX. INTELL. PROP. L.J. 413, 450–54 (2009).

396. See *Golden Rice and Intellectual Property*, GOLDEN RICE PROJECT, http://www.goldenrice.org/Content2-How/how9_IP.php (last visited Oct. 11, 2016); Amanda L. Brewster, Audrey R. Chapman & Stephen A. Hansen, *Facilitating Humanitarian Access to Pharmaceutical and Agricultural Innovation*, 1 INNOVATION STRATEGY TODAY 203, 205 (2005).

persuaded more than thirty academic and industrial holders of patents relevant to golden rice to license these patents to a non-profit organization for sublicensing on favorable terms for use by farmers in developing countries.³⁹⁷

Another prominent example of philanthropic patent pooling for global public health is the Medicines Patent Pool (MPP), which was launched in 2009 to improve access to affordable HIV/AIDS medications in the developing world.³⁹⁸ The MPP seeks royalty-free licenses from pharmaceutical patent holders and in turn grants low- or no-cost sublicenses to manufacturers that commit to produce and sell drugs to users in low-income countries.³⁹⁹ A few significant patent holders, including NIH and Gilead Sciences, have contributed licenses to the MPP; others who own relevant patents have declined to participate.⁴⁰⁰

Just as governments can issue compulsory patent licenses, they can also encourage the formation of patent pools when blocking patents or patent thickets may create perceived problems with technology development or dissemination. For example, in the early twentieth century, the aviation industry was subject to a series of patent disputes and litigation between rival aircraft manufacturers Wright-Martin Aircraft Corp. (successor to the Wright brothers' original aviation patent) and Curtiss Aeroplane & Motor Corp.⁴⁰¹ These disputes gave rise to fears within the United States government (primarily voiced by then-Acting Secretary of the Navy Franklin Delano Roosevelt) that the production capacity of the U.S. aviation industry could be hindered in a manner detrimental to U.S. engagement in World War I.⁴⁰² As a result of this intervention, the U.S. aviation industry formed the Manufacturers' Aircraft Association (MAA), a patent pool that

397. See generally GOLDEN RICE PROJECT, *supra* note 396.

398. See *Medicines Patent Pool Announces First Licensing Agreement with a Pharmaceutical Company*, MEDS. PAT. POOL (July 12, 2011), <http://www.medicinespatentpool.org/medicines-patent-pool-announces-first-licensing-agreement-with-a-pharmaceutical-company/>.

399. See *About the MPP*, MEDS. PAT. POOL, <http://medicinespatentpool.org/about/> (last visited Oct. 11, 2016).

400. See Mattioli, *supra* note 389, at 124–25.

401. See *Mfrs. Aircraft Ass'n, Inc. v. United States*, 77 Ct. Cl. 481 (1933) (granting royalties for aircraft manufactured with patented technologies).

402. See *id.* (detailing the difficulties faced by the Army and Navy regarding patented aircraft technology and wartime production in 1917 and 1918).

provided for cross-licensing of aviation patents among the pool members, among other things.⁴⁰³

Proposals regarding patent pools have also been made in connection with climate change emissions abatement and SCE technologies.⁴⁰⁴ These proposals are addressed below in Section VI.A.

2. Patent Pledges

As discussed above, the formation of a patent pool requires a substantial amount of legal planning including the definition of rights as among pool members, the identification and appointment of a pool administrator, and careful attention to the relationship among patents included in the pool. Over the past decade, patents holders have found it increasingly expedient to make commitments regarding the enforcement and licensing of their patents without the legal trappings, infrastructure, and overhead of a formal patent pool.⁴⁰⁵ These commitments—“patent pledges”—are promises made by patent holders to limit the enforcement or other exploitation of their patents.⁴⁰⁶ The promises are made not to specific parties, as in traditional bilateral contracts, but to the market at large.⁴⁰⁷ A range of legal theories have been advanced to enable third parties to rely on patent pledges as legally-binding commitments.⁴⁰⁸ For the most part, such pledges are made

403. The formation of the MAA and its aftermath have been discussed extensively in the literature. See, e.g., Ron D. Katznelson & John Howells, *The Myth of the Early Aviation Patent Hold-Up—How a US Government Monopsony Commandeered Pioneer Airplane Patents*, 24 INDUS. & CORP. CHANGE 1, 3 (2015); Jorge L. Contreras, *A Brief History of FRAND: Analyzing Current Debates in Standard-Setting and Antitrust through a Historical Lens*, 80 ANTITRUST L.J. 39, 69 (2015); Mattioli, *supra* note 389, 130–33 (2012); Robert P. Merges, *Contracting into Liability Rules: Intellectual Property Rights and Collective Rights Organizations*, 84 CALIF. L. REV. 1293, 1342–47 (1996).

404. See, e.g., Chavez, *supra* note 125 (advocating for a geoengineering patent pool).

405. See generally Jorge L. Contreras, *Patent Pledges*, 47 ARIZ. ST. L.J. 543, 543 (2015) [hereinafter Contreras, *Patent Pledges*] (offering a “four-part taxonomy of patent pledges based on the factors that motivate patent holders to make them and the effect they are intended to have on other market actors”).

406. See *id.* at 543

407. See *id.*

408. See, e.g., Jorge L. Contreras, *A Market Reliance Theory for FRAND Commitments and Other Patent Pledges*, 2015 UTAH L. REV. 479 [hereinafter Contreras, *Market Reliance*] (describing a range of existing theories for

without direct compensation or other consideration being transferred directly to the patent holder.⁴⁰⁹ This is not to say, however, that patent pledges are economically irrational; they may be supported by motivations ranging from promoting market development to acquiring platform leadership to improving public relations.⁴¹⁰

Another recent trend has been to make pledges that are likely to reduce the threat of non-practicing entity (NPE) litigation. For example, in 2015 the non-profit DPL Foundation launched the Defensive Patent License (DPL) program, in which firms may publicly post their commitments to license all of their patents to other firms making similar commitments, while retaining the right to use the patents for counter-claiming when sued.⁴¹¹ The license that they promise to grant is on standardized terms developed by the DPL Foundation, with input from various communities.⁴¹² The express purpose of the DPL is to discourage transfers of patents to PAEs; and to that end it permits a patent holder to revoke any DPL license if the licensee either brings a patent infringement claim against another DPL pledgor or transfers a patent to an entity that has not made a DPL pledge.⁴¹³

Patent pledges range from well-documented, uniform commitments made by firms participating in technical standards-setting organizations to relatively informal, one-off commitments such as the 2014 public announcement by Tesla Motors CEO Elon Musk that his company would no longer

enforcement of patent pledges including contract, antitrust, servitude, and reliance-based theories).

409. See Contreras, *Patent Pledges*, *supra* note 405, at 546.

410. See *id.* at 591 (noting the public relations benefits of pledging).

411. Frequently Asked Questions, DEFENSIVE PAT. LICENSE, <http://defensivepatentlicense.org/content/frequently-asked-questions#how-can-i-start> (last visited Oct. 11, 2016); *cf.* *Non-Sticky Defensive Patent License*, GOOGLE, <https://www.google.com/patents/licensing/dpl/non-sticky/> (last visited Oct. 11, 2016) (distinguishing the non-sticky DPL from the sticky DPL by the ability to withdraw and revoke prior authorizations). See generally Jason Schultz & Jennifer Urban, *Protecting Open Innovation: The Defensive Patent License as a New Approach to Patent Threats, Transaction Costs, and Tactical Disarmament*, 26 HARV. J.L. & TECH. 1 (2012).

412. *The Defensive Patent License 1.1*, DEFENSIVE PAT. LICENSE, <http://defensivepatentlicense.org/content/defensive-patent-license> (last visited Nov. 11, 2016).

413. *Id.* § 2(e).

“initiate patent lawsuits against anyone who, in good faith, wants to use [its] technology.”⁴¹⁴

Patent pledges, such as Tesla’s, have increasingly been used to promote environmentally friendly “green/clean” technologies. One of the best-known green patent pledges was the Eco-Patent Commons (EPC), formed by coalition of large industrial firms including IBM, Nokia, Sony, DuPont, Dow, HP, Sony, and Xerox.⁴¹⁵ To join EPC, each member firm had to identify specific environment-related patents and commit not to assert those patents against any technology that “reduces/eliminates natural resource consumption, reduces/eliminates waste generation or pollution, or otherwise provides environmental benefit(s).”⁴¹⁶ The EPC, which was managed by the Environmental Law Institute in Washington, DC, reports that over 100 “eco-friendly patents” were pledged by its members since it was formed in 2008.⁴¹⁷ Participants in the EPC were required to apply to join,⁴¹⁸ and comply with a detailed set of “Ground Rules” that included the terms of the pledge and other details regarding membership.⁴¹⁹ One criticism of the EPC (and similar pledge communities), however, is that the participating firms did not make pledges with respect to core technologies or commercially and competitively valuable patents.⁴²⁰ A more recent evaluation found that the pledged patents were more valuable than average patents held by contributing firms and also more valuable than comparable patents protecting similar

414. See Elon Musk, *All Our Patents Are Belong to You*, TESLA BLOG (June 12, 2014), <http://www.teslamotors.com/blog/all-our-patent-are-belong-you>. See generally Contreras, *Patent Pledges*, *supra* note 405, at 558 (cataloging the different types of patent pledges made).

415. See THE ECO-PATENT COMMONS, <https://ecopatentcommons.org/> (last visited Nov. 16, 2016).

416. See generally WORLD BUS. COUNCIL FOR SUSTAINABLE DEV., ECO-PATENT COMMONS GROUND RULES 6, <http://www.wbcd.org/pages/adm/download.aspx?id=314&objectypeid=7> [hereinafter EPC GROUND RULES].

417. See *Frequently Asked Questions*, ECO-PATENT COMMONS, <http://ecopatentcommons.org/frequently-asked-questions#QA14> (last visited Oct. 11, 2016).

418. *Joining or Submitting Additional Patents to the Commons*, ECO-PATENT COMMONS, <http://ecopatentcommons.org/join> (last visited Nov. 16, 2016) (listing the procedures for joining the EPC).

419. See EPC GROUND RULES, *supra* note 416.

420. See, e.g., Deborah Behles, *The New Race: Speeding Up Climate Change Innovation*, 11 N.C. J.L. & TECH. 1, 20 (2009) (emphasizing the inability of the EPC “to attract the core innovation . . . needed to combat climate change”).

technologies, but were for more derivative and narrower technologies (*i.e.*, less radical inventions) and less central to the firms' patent portfolios (suggesting they are not valuable to the firms owning them).⁴²¹ Further, although the evidence was preliminary, pledging of the patents to the EPC had “no discernible impact on the diffusion” of the patented technologies.⁴²² The EPC ceased active operations in May 2016, though the pledges made by its members prior to its discontinuation remain in effect.⁴²³

Not all patent pledges require non-assertion or royalty-free licensing of the pledgor's patents. In fact, the most common forms of pledges are made in the context of technical standard-setting. These pledges often commit the patent holder to license its patents that are essential to a standard to manufacturers of standardized products, but permit it to charge patent royalties so long as they are “fair, reasonable and non-discriminatory” (FRAND).⁴²⁴ There has been significant debate (and litigation) concerning the precise level of royalties that may be charged when the patent holder is subject to a FRAND commitment, whether a FRAND commitment precludes a patent holder from seeking injunctive relief against infringers, and whether other types of license terms comply with FRAND obligations.⁴²⁵ Nevertheless, such commitments, at a minimum, ensure access

421. See Bronwyn H. Hall & Christian Helmers, *Innovation and Diffusion of Clean/Green Technology: Can Patent Commons Help?* 21 (Nat'l Bureau of Econ. Research, Working Paper No. 16920, 2011), <http://www.nber.org/papers/w16920>.

422. See *id.*

423. *Important Statement from the Board: Eco-Patent Commons to Cease Active Operations Effective May 18, 2016*, ECO-PATENT COMMONS, <https://ecopatentcommons.org> (last visited Dec. 1, 2016).

424. See, e.g., Mark A. Lemley & Carl Shapiro, *Patent Holdup and Royalty Stacking*, 85 TEX. L. REV. 1991 (2007); Joseph Farrell et al., *Standard Setting, Patents, and Hold-Up*, 74 ANTITRUST L.J. 603, 616 (2007); Jorge L. Contreras & Richard J. Gilbert, *A Unified Framework for RAND and Other Reasonable Royalties*, 30 BERKELEY TECH. L.J. 1451 (2015); J. Gregory Sidak, *The Meaning of FRAND, Part I: Royalties*, 9 J. COMPETITION L. & ECON. 931, 931 (2013).

425. See generally Jorge L. Contreras, *Patents, Technical Standards and Standard-Setting Organizations: A Survey of the Empirical, Legal and Economics Literature*, in 2 RESEARCH HANDBOOK ON THE ECONOMICS OF INTELLECTUAL PROPERTY LAW (Peter S. Menell & David Schwartz eds., forthcoming 2017), https://papers.ssrn.com/sol3/Papers.cfm?abstract_id=2641569 (reviewing extensively the literature on “reasonable royalty” patent damages and license on terms that are reasonable and non-discriminatory).

to patents and prevent patent holders from electing to assert blocking positions against other market participants.

3. Data Commons

While patent pools and patent pledges seek to address potential barriers to innovation and technology development that may arise from the existence of blocking patents or patent thickets, another way to facilitate innovation and development is through the sharing and dissemination of research data. When data sharing is conducted in a systematic manner and data is made available through a broadly accessible repository or set of repositories, this structure is often referred to as a “data commons.”⁴²⁶

Many important data commons have arisen as a result of government-procurement and research-funding requirements discussed in Subsection V.A.5 above. Today, vast aggregations of astronomical, atmospheric, geo-locational, genomic, and other research data are accessible to researchers and the public worldwide as a result of these programs.⁴²⁷ However, not all data commons arise as a result of government intervention. In the 1990s, pharmaceutical giant Merck released a database of more than 800,000 short DNA sequences known as ESTs to the public.⁴²⁸ While this data was a boon to genetic research, it is also believed that Merck created the so-called “Merck Gene

426. See, e.g., Reichman & Uhler, *supra* note 291, at 335–36 (highlighting the importance of the availability of information in the scientific research community, as compared to industry); Charlotte Hess & Elinor Ostrom, *An Overview of the Knowledge Commons, introduction to UNDERSTANDING KNOWLEDGE AS A COMMONS: FROM THEORY TO PRACTICE 3* (Charlotte Hess & Elinor Ostrom, eds. 2007) (exploring the interpretation of “commons” in a multiple disciplines); Yochai Benkler, *Between Spanish Huertas and the Open Road: A Tale of Two Commons?*, in *GOVERNING KNOWLEDGE COMMONS 69* (Brett M. Frischmann, Michael J. Madison & Katherine J. Strandburg eds., 2014) (harmonizing the concepts of commons and property ownership).

427. These include the National Library of Medicine’s GenBank and dbGaP databases of genomic data, NASA’s National Space Science Data Center, the National Center for Atmospheric Research (NCAR), and the U.S. Geological Survey’s Earth Resources Observation Systems (EROS) Data Center.

428. See Press Release, Merck & Co., Inc., First Installment of Merck Gene Index Data Released to Public Databases: Cooperative Effort Promises to Speed Scientific Understanding of the Human Genome (Feb. 10, 1995), <http://www.bio.net/bionet/mm/bionews/1995-February/001794.html> [hereinafter Merck Gene Index Press Release] (announcing the beginning of the project); DON TAPSCOTT & ANTHONY D. WILLIAMS, *WIKINOMICS: HOW MASS COLLABORATION CHANGES EVERYTHING 166* (2006).

Index” to pre-empt the filing of EST patents by biotechnology companies seeking to capitalize on these new discoveries.⁴²⁹

In 1999, toward the end of the public HGP, a group of large pharmaceutical and information technology companies and the Wellcome Trust formed a joint collaboration referred to as the SNP Consortium.⁴³⁰ The purpose of this non-profit entity was to identify and map genetic markers referred to as SNPs and to contribute the resulting data to the public domain.⁴³¹ The consortium ultimately mapped approximately 1.5 million SNPs and created a genome-wide SNP-based human linkage map.⁴³² As the SNPs were identified, they were validated, mapped, and deposited in publicly available databases maintained by the consortium and NIH’s National Center for Biotechnology Information.⁴³³

Like Merck with the Merck Gene Index, the members of the SNP Consortium wished to generate data for the use of all researchers, free from patent encumbrances.⁴³⁴ The consortium adopted a multi-prong approach to ensure that the SNP data it discovered would not be patented.⁴³⁵ First, it contractually

429. See Eliot Marshall, *Bermuda Rules: Community Spirit, With Teeth*, 291 SCI.1192 (2001); see also TAPSCOTT & WILLIAMS, *supra* note 428; Rai, *supra* note 222, at 134 (noting that firms including Incyte Pharmaceuticals and Human Genome Sciences were already seeking to patent and license ESTs and other genetic data).

430. See Arthur L. Holden, *The SNP Consortium: Summary of a Private Consortium Effort to Develop an Applied Map of the Human Genome*, 32 BIOTECHNIQUES 22 (2002).

431. See *id.*; Contreras, *Bermuda’s Legacy*, *supra* note 220, at 95–97.

432. See Holden, *supra* note 430, at 25–26; see also Gudmundur A. Thorisson & Lincoln D. Stein, *The SNP Consortium Website: Past, Present and Future*, 31 NUCLEIC ACIDS RES. 124, 124–27 (2003) (offering a detailed description of the consortium’s web-based data resource).

433. See generally S.T. Sherry et al., *dbSNP: The NCBI Database of Genetic Variation*, 29 NUCLEIC ACIDS RES. 308, 308–11 (2001) (instructing the user of the utility as well as procedures for contributing to the SNP database).

434. See, e.g., Holden, *supra* note 430, at 26 (“The overall IP objective is to maximize the number of SNPs that (i) enter the public domain at the earliest possible date, and, (ii) are free of third-party encumbrances such that the map can be used by all without financial or other IP obligations.”); TAPSCOTT & WILLIAMS, *supra* note 428, at 168 (noting the concern of some consortium members’ regarding announced plans by biotech firms “to patent SNPs and sell them to the highest bidder”).

435. TSC’s patent deterrence strategies are described in detail in Contreras, *Bermuda’s Legacy*, *supra* note 220, at 95–97. Contreras served as TSC’s legal counsel responsible for developing and overseeing the implementation of these strategies. TSC’s defensive patenting strategy has been favorably cited in the literature. See, e.g., Mattioli, *supra* note 389, at 129; Robert Merges, *A New Dynamism in the Public Domain*, 71 U. CHI. L.

prohibited the sequencing centers performing SNP identification and mapping activity from filing for patent protection on their discoveries.⁴³⁶ Second, it released all SNP data it discovered to public databases, thus creating voluminous prior art against potential patent filings by others.⁴³⁷ Finally, it adopted a novel “defensive” patenting strategy in which it filed patent applications disclosing all newly identified and mapped SNPs with the USPTO in order to enter this data into the USPTO prior art database and to establish clear priority dates to defeat later patent applications.⁴³⁸ The consortium’s patent applications were later converted into Statutory Invention Registrations (SIRs) or, following the 1998 revision to the Patent Act to implement the WTO TRIPS Agreement,⁴³⁹ published and then allowed to go abandoned.⁴⁴⁰ None of the consortium’s applications were prosecuted to issuance, but instead utilized the USPTO publication system to deter independent patenting of discovered SNPs.⁴⁴¹

Despite this active patent deterrence program with respect to basic SNP data, the consortium made it clear that

REV. 183 (2004); Rebecca Eisenberg, *The Promise and Perils of Strategic Publication to Create Prior Art: A Response to Professor Parchomovsky*, 98 MICH. L. REV. 2358 (2000).

436. See Contreras, *Bermuda’s Legacy*, *supra* note 220, at 93.

437. See *id.* at 96–97.

438. Although any genomic data released to the public (e.g., through NIH’s GenBank database) can act as prior art defeating a later patent application, it is often inconvenient for patent examiners to search databases external to the USPTO. Moreover, it is often difficult to establish the precise date that data was uploaded to a particular public database. For these reasons, TSC elected to submit its SNP data directly to the USPTO by means of provisional patent applications. See Contreras, *Bermuda’s Legacy*, *supra* note 220, at 96–97 n.151 (“The SNP Consortium’s patenting strategy included the filing of patent applications covering all mapped SNPs and then converting those applications into statutory invention registrations (SIRs) or abandoning the applications after publication.”).

439. American Inventors Protection Act of 1999, Pub. L. 106–113, Div. B, § 1000(a)(9) [Title IV, § 4502(a)], 113 Stat. 1536 (1999) (codified at 35 U.S.C. § 122(b) (2012)) (requiring publication of applications within eighteen months of their priority date, absent certain conditions or a request based on certification that the application will not be filed abroad).

440. See Contreras, *Bermuda’s Legacy*, *supra* note 220, at 97 n.151.

441. See Jorge L. Contreras, Aris Floratos & Arthur L. Holden, *The International Serious Adverse Events Consortium’s Data Sharing Model*, 31 NATURE BIOTECH. 17, 18 (2013) (noting also that “[t]he patent-defeating effect of such patent filings extends to any other country that is a treaty partner of the United States”).

participants were free to pursue patents based on discoveries made using SNPs.⁴⁴² Thus, the SNP map created by the SNP Consortium was intended to act as a public research tool, but not to prevent patenting of downstream diagnostics or therapeutics developed by participants or others.⁴⁴³

The SNP Consortium's data commons approach has served as a model for the ways that private industry can advance science by ensuring that data remains free and available for all to use without patent encumbrances.⁴⁴⁴

VI. POSSIBLE INTELLECTUAL PROPERTY POLICIES FOR SOLAR CLIMATE ENGINEERING

In this Part, we evaluate proposals for SCE IP policy that others have made, and offer recommendations of our own. Before doing so, it is important to highlight a handful of relevant SCE characteristics that may affect the choice of approach. First, as described in Part II above, SCE could eventually develop into a moderately large industry, most likely supported through public procurement.⁴⁴⁵ Second, as described in Part III above, there is presently only a low level of SCE patenting activity and no evidence of broad trade secrecy.⁴⁴⁶ Instead, research is mostly funded by public sources and occurs at universities and other non-industry research institutions, at which researchers currently seem to share their data willingly.⁴⁴⁷ Third, SCE research and possible implementation will necessarily be transnational.⁴⁴⁸ Fourth, SCE remains politically contested, and public decision makers

442. See generally *id.* (describing the “data release and IP policies of the International Serious Adverse Events Consortium (iSAEC)”).

443. One concern that has been raised regarding such “open data” approaches is that they do not obligate downstream users from refraining to seek IP protection on discoveries or inventions made using the data. Open data approaches are thus unlike so-called “copyleft” or “viral licensing” approaches that have been adopted in regard to open-source software and some database licenses (where the initial IP rights or rights of access are used to obtain reproducible, contractual obligations on downstream behaviors). See generally BERNARD GOLDEN, SUCCEEDING WITH OPEN SOURCE 44–45 (2005) (discussing viral licensing).

444. For other examples of private sector data commons in the biosciences, see, e.g., Contreras et al., *supra* note 441.

445. See discussion *supra* Part II.

446. See discussion *supra* Part III.

447. See *supra* Subsection V.A.5 and accompanying notes.

448. See *supra* notes 68–71 and accompanying text.

presently appear to be reluctant to engage with it.⁴⁴⁹ Fifth, the line between SCE and non-SCE research is unclear.⁴⁵⁰ In particular, inventions made during the course of SCE research may have beneficial applications outside of SCE.⁴⁵¹ Likewise, inventions made outside of SCE research may become essential for the further R&D and potential implementation of SCE.⁴⁵² Of course, some or all of these characteristics could change as SCE R&D matures.

A. ASSESSMENT OF EXISTING PROPOSALS

1. Legislative and Administrative Limits on Patentability of SCE Technologies

As noted above, some commentators have pointed to legislative enactments such as the patent-limiting features of the AEA as models for potentially restricting the patentability of SCE technologies.⁴⁵³ These proposals share a number of weaknesses. First, proposals to amend patent laws must consider the national character of patent rights and the likely international character of any SCE research or implementation.⁴⁵⁴ Patent legislation in any single jurisdiction will not have a substantial impact on research or implementation activity in other jurisdictions.⁴⁵⁵ At a minimum, the principal North American, European, Asian, Latin American, African, and Oceanic economies would need to adopt corresponding statutory amendments if they are to be meaningful. Thus, if SCE is to be addressed through special patent-related legislation, it would need to be coordinated on an international scale, most likely through a multinational treaty or an amendment to TRIPS Article 27.2 that would *require*, rather than merely permit, prohibitions on patenting SCE technologies as “necessary . . . to avoid serious prejudice to

449. *See supra* Section IV.E.

450. *See supra* note 174 and accompanying text.

451. *See supra* note 176 and accompanying text.

452. *See supra* note 175 and accompanying text.

453. *See, e.g.*, Chavez, *supra* note 125, at 18–19; Parthasarathy et al., *supra* note 315, at 9–12. *See also* Anne C. Mulkern, *Researcher: Ban Patents on Geoengineering Technology*, SCI. AM., <http://www.scientificamerican.com/article/researcher-ban-patents-on-geoengineering-technology/> (last visited Feb. 22, 2016) (quoting a leading SCE researcher rejecting SCE patents and arguing that “[t]he core technologies need to be public domain”).

454. *See* discussion *supra* Section IV.D.

455. *See id.*

the environment.”⁴⁵⁶ It is our assessment, particularly given the recent aggressive pro-patent positions of some developed countries in international trade negotiations,⁴⁵⁷ that such coordination or a new multilateral treaty is unlikely to emerge in the near future. Nor do we believe that wholesale field-of-technology-based exclusions should be adopted, absent a clear demonstration that the technologies pose significant public safety risks similar to concerns that animated the exclusion for nuclear weapons technologies.

Further, the question remains whether limitations on the patentability of SCE technologies would be likely to promote or hinder innovation in this critical area. The answer is far from clear. We would be concerned with granting patent rights in this area to the extent that applicants would seek to claim (1) scientific or natural discoveries themselves; (2) analogous, uncreative applications of the discovered properties of natural phenomena; or (3) trivially modified natural materials employing the discovered properties for SCE purposes (unless doing so reflects non-analogous creativity).⁴⁵⁸ As discussed above in Section IV.A above, significant deontological as well as

456. TRIPS Agreement, *supra* note 285, at art. 27.2.

457. See, e.g., William New, *Leaked TPP Draft Reveals Extreme Rights Holder Position of US, Japan Outraged Observers Say*, INTELL. PROP. WATCH (Oct. 17, 2014), <http://www.ip-watch.org/2014/10/17/leaked-tpp-draft-reveals-extreme-rights-holder-position-of-us-japan-outraged-observers-say/>; cf. David Vivas Eugui, *A Shift in International Property Policy in US FTAs?*, BRIDGES Aug. 1, 2007, <http://www.ictsd.org/bridges-news/bridges/news/a-shift-in-intellectual-property-policy-in-us-ftas> (“In a substantial departure from past practice, the US recently relaxed several patent-related IP rules in revised versions of its FTAs with Colombia, Panama and Peru.”).

458. As some of the authors have discussed, at least in the United States, scientific and natural discoveries by applicants are to be treated as if they are “prior art” when disclosed in patent applications, thus only *creative* (or “inventive”) applications of the discovered science or natural materials should be considered patent-eligible inventions. See Sarnoff, *Patent-Eligible Inventions After Bilski*, *supra* note 199, at 77–84; Brief of Fifteen Law Professors as Amici Curiae Supporting of Petitioners, *Association for Molecular Pathology v. Myriad Genetics, Inc.*, 133 S.Ct. 2107 (2013) (No. 12-398), 2013 WL 432950; cf. Jeffrey A. Lefstin, *Inventive Application: A History*, 67 FLA. L. REV. 565, 570, 623–31 (2015) (discussing the relevant English and American history and arguing that “[i]t was not until 1948, when the Supreme Court decided *Funk Brothers Seed Co. v. Kalo Inoculant Co.*, that a test of inventive application entered the mainstream of American patent law.”); Joshua D. Sarnoff, *Inventive Application, Legal Transplants, Pre-Funk, and Judicial Policymaking* (forthcoming 2017) (on file with author) (arguing that the creative application requirement was deeply engrained in American patent law well before *Funk Brothers*, that it should not be abandoned, and that other jurisdictions should adopt it).

utilitarian concerns would arise if patents were granted on basic scientific principles and natural materials, or on fundamental, upstream technologies.⁴⁵⁹ But reaching a consensus that would span the globe on these highly contentious issues is unlikely for the foreseeable future. Fortunately, the authors believe that most SCE technologies that will be developed are unlikely to be fundamental natural discoveries or research tools (such as DNA sequences and basic biomedical discoveries that the NIH and later the USPTO sought to keep outside of the patent system). Rather, they are more likely to be specialized, creative applications of well-known scientific principles, materials, and processes that are designed for direct deployment and utilization, or product and process technologies that will facilitate SCE research.⁴⁶⁰

In summary, in order to make the greatest range of technical options available to those having responsibility for assessing the risks and benefits of SCE, competition among as many different technological approaches as possible is desirable. Adopting limits to patenting of fundamental upstream technologies beyond the existing limits on patenting discoveries (and in some jurisdictions, non-creative applications of those discoveries) may, in theory, be beneficial and authorized under current law.⁴⁶¹ But in practice, additional limits on patenting may not be needed given the likely development pathway for SCE technologies; the likelihood that such enactments would encounter significant political opposition; and (most importantly) that such enactments are not necessarily the most effective means by which governments

459. See *supra* Part IV.A. Note that the treatment of natural discoveries as prior art corresponds to the historical deontological views of scientists' normative duty to freely share their discoveries for the benefit of society, and that such sharing simultaneously achieves utilitarian goals. See *supra* note 200 and accompanying text.

460. We see analogies here to the DNA sequencing equipment and methodologies that were developed during and after the HGP by the private sector, partially with NIH funding, to facilitate government-funded research. This equipment and technology was subject to intense commercial competition, leading to rapid and unpredicted advances in capabilities at continually decreased cost. See, e.g., KEVIN DAVIES, *THE \$1,000 GENOME: THE REVOLUTION IN DNA SEQUENCING AND THE NEW ERA OF PERSONALIZED MEDICINE* 8–11 (2010); Henrik Stranneheim and Joakim Lundberg, *Stepping Stones in DNA Sequencing*, 7 *BIOTECHNOLOGY* J. 1063, 1063 (2012); Erik Pettersson et al., *Generations of Sequencing Technologies*, 93 *GENOMICS* 105 (2008).

461. See *supra* notes 220–24 and accompanying text.

can assure widespread and low-cost access to the relevant discoveries and applications. This is particularly true when a government funds the development of the relevant technologies, and thus may possess rights to use them or to assure widespread access at reasonable costs, as discussed below. Accordingly, we do not currently recommend the adoption of additional legislative or administrative limits on patenting SCE technologies.

2. Government Limitation, Use, Retention, or March-In of Patent Rights

Assuming the continued availability of patents on SCE technologies, some have argued for governments to limit the exercise of such rights through compulsory licensing.⁴⁶² We believe that such proposals fail to recognize the broad range of powers that governments may exercise in regard to government-funded inventions. Specifically, as discussed above, governments may already possess rights to use patented inventions for free, to impose conditions on the exercise of such patent rights, or to exercise march-in rights in order to ensure that critical technologies remain available for broad use at reasonable costs.⁴⁶³

Under the Bayh-Dole Act, for example, the U.S. Government retains for any government-funded, privately patented invention “a nonexclusive, nontransferrable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States any subject invention throughout the world.”⁴⁶⁴ Such action would not require *any* payments to the patent holder, and would not restrict any rights of the patent holder (although it may reduce the compensation that the patent holder expected to receive). As noted above, the government also may use *any* patented technology that is *not* subject to the governmental licensing provision for funded inventions, although it then may be obligated to provide reasonable compensation if successfully sued for patent infringement.⁴⁶⁵ This would leave to the courts the decision of how much compensation is “reasonable.”

Further, for government-funded inventions,

462. See *supra* note 358 and accompanying text.

463. See discussion *supra* Section V.A.

464. 35 U.S.C. § 202(c)(4) (2012).

465. See *supra* Subsection V.A.3.

the funding agreement may provide for such additional rights; including the right to assign or have assigned foreign patent rights in the subject invention, as are determined by the agency as necessary for meeting the obligations of the United States under any treaty, international agreement, arrangement of cooperation, memorandum of understanding, or similar arrangement.⁴⁶⁶

To the extent that SCE becomes important to meeting commitments that the United States may make under the UNFCCC's Paris Agreement or other international climate treaties, additional requirements could be added that would assure widespread access at reasonable cost for third parties to use the patented technologies.

Additionally, when the U.S. Government funds such privately patented technologies, it retains the right to require the patent holder or an exclusive licensee to grant licenses to others on reasonable terms.⁴⁶⁷ Although the U.S. Government has not to date used this authority to compel third-party licensing of technologies,⁴⁶⁸ it could do so in the case of SCE technology. Other countries have similar legal mechanisms as well as more general compulsory licensing authorities that could compel such access on reasonable terms.⁴⁶⁹

Finally, as SCE technologies are likely to be developed in a monopsony government market,⁴⁷⁰ there is unlikely to be a need for governments to “appropriate” *privately* funded SCE patent rights by infringing such rights and courting compensation suits (unless the patent holders negotiate unreasonably). Our greatest concern with potential governmental use of SCE patent rights or efforts to assure third-party access to patented SCE technologies at reasonable costs, however, arises from the potential impact that such actions could have on researchers' behavior. In particular, researchers, anticipating that the state may later limit their pecuniary rewards, may react in several ways that would reduce research and innovation in this important area. For example, they may reduce R&D expenditures and redirect them toward other technology areas that are less likely to be subject to governmental appropriation.

Alternatively, researchers may continue SCE R&D but shift their legal strategies away from patenting and toward

466. 35 U.S.C. § 202(c)(4).

467. See *supra* note 341 and accompanying text

468. See *supra* notes 341–45 and accompanying text.

469. See *supra* notes 354–57 and accompanying text.

470. See discussion *supra* II.B.

trade secrecy. Such a shift could have substantial negative effects on the development of SCE technologies.⁴⁷¹ Overall knowledge and understanding are less likely to advance when each organization keeps its results and discoveries secret. Moreover, increased secrecy in SCE research is likely to reduce levels of collaboration and cooperation, both among between academic institutions, governmental agencies, and private actors. Finally, the existence of trade secrets could serve to heighten SCE's political controversy and to hinder its effective governance.⁴⁷² All of these effects are likely to reduce innovation and discovery in a crucial area of research.

3. Patent Pools

Some commentators, looking to the century-old example of the Wright-Curtiss aviation patent wars and the U.S. Government's intervention leading to the formation of the MAA,⁴⁷³ have suggested a similar approach for SCE technologies.⁴⁷⁴ That is, the formation of a formal patent pool, whether voluntarily or under governmental pressure or mandate, to aggregate relevant SCE patents and make them available to all market participants for exploitation.

Despite the initial appeal of such a framework, it is unclear to us whether a patent pooling approach—especially if government initiated or compelled—is appropriate or desirable for SCE. First, the domestic political and industrial landscape today is very different than it was at the dawn of World War I. State efforts to compel market participants to form a patent pool today would be subject to numerous political and legal challenges. In particular, such a maneuver, absent some anticompetitive conduct by patent holders or governmental funding of the patented technology, would likely be challenged as a governmental appropriation of property rights, and thus be subject to compensation under the Takings Clause of the

471. See discussion *supra* Section IV.C.

472. A telling example occurred when BP refused to release large amounts of environmental and other data relating to the catastrophic Deepwater Horizon oil spill. See Amanda Mascarelli, *Freedom of Spill Research Threatened*, 466 NATURE 538, 538 (2010), <http://www.nature.com/news/2010/100728/full/466538a.html>; Lauren Schenkman, *After Outcry, Oil Data Inches into the Open*, 329 SCIENCE 888, 888 (2010) (describing BP's retreat from its initial position following public criticism of its data concealment practices).

473. See *supra* notes 401–03 and accompanying text.

474. See Chavez, *supra* note 125, at 28–29.

Fifth Amendment to the U.S. Constitution.⁴⁷⁵ Although the outcome of such a suit would be uncertain (particularly if the government did not require royalty free licensing), it would again raise significant concerns about redirecting investment and legal strategies towards trade secrecy.

Moreover, unlike the production of military aircraft to support the national war effort (a domestic issue), the research, development, and possible implementation of SCE technologies is inherently international. Thus, a U.S.-only patent pool, no matter how comprehensive, would fall short of achieving necessary global acceptance. Yet the prospect of compelling firms worldwide to participate in an international patent pool, without any credible international governmental leverage, seems a daunting task.

Of course, market participants often enter patent pooling initiatives voluntarily, without governmental pressure or intervention. The voluntary formation of one or more formal, centralized patent pools among holders of SCE patents thus seems possible. However, we do not view such a development as necessary (and it may not even be beneficial) for SCE research, development, and implementation.

One reason a patent pool is likely to yield limited benefits is that, as discussed above,⁴⁷⁶ under current U.S. and European competition and antitrust laws, patent pools may only include patents claiming technologies that are complementary to one another, and not technologies that are substitutes.⁴⁷⁷ Accordingly, patent pools will only be necessary if significant patent blocking or thickets develop, and currently there are few patents on SCE technologies.⁴⁷⁸ Another reason is that, while pooling approaches are beneficial in markets in which many patents cover relatively narrow technical solutions (such as particular standards for data encoding or compression),⁴⁷⁹ they are less beneficial when the market has not yet settled on a

475. *See, e.g.*, *United States v. Hartford-Empire Co.*, 323 U.S. 386, 414–15 (1945) (holding that a court-ordered mandatory royalty-free patent license would constitute an unjustified “confiscation” of the patent holder’s property).

476. *See supra* notes 391–95 and accompanying text.

477. *See* ANTITRUST AND IPR, *supra* note 390, at 76–78; *cf.* Jorge L. Contreras, *Fixing FRAND: A Pseudo-Pool Approach to Standards-Based Patent Licensing*, 79 ANTITRUST L.J. 47, 77 n.115 (2013) [hereinafter, Contreras, *Fixing FRAND*] (citing cost of \$10,000 to \$15,000 per patent for essentiality evaluation in pool formation).

478. *See supra* Section III.A.

479. *See supra* note 389 and accompanying text.

preferred technical direction or technology. Thus, in a field such as SCE, in which no particular technical approach has become dominant and in which many potential directions are likely to emerge,⁴⁸⁰ the creation of one or a few patent pools around particular, but uncertain and untested, approaches appears to be of limited use. In other words, a patent pool could help to generate undesirable technological lock-in. At this early stage of research and technology development, the field will likely benefit from the emergence of as many different and innovative ideas as possible, rather than from the consolidation of patent positions around one or a few early technologies.

4. Defensive Patenting and Publishing

Some SCE researchers have already begun to file patent applications on certain SCE technologies and approaches not with a goal of commercializing or profiting from such protection, but in order to preclude patenting by others.⁴⁸¹ This “defensive” patenting approach, which is similar to that discussed in Subsection V.B.3 above,⁴⁸² can place relevant prior art into patent office databases, thereby making it easier for patent examiners to disallow subsequent patent claims on the technology. Similar results may be achieved by publishing research findings in publicly-available literature (so-called “defensive publication”),⁴⁸³ though the specificity and prior art value of publications is usually less than that of other patent applications. The advantage of publication over patenting, of course, are reduced cost and effort on the part of the researcher. In both cases, subsequent patents may be allowed over such prior art if the applicant can demonstrate sufficiently differentiating improvements or differences over the previously disclosed technology.⁴⁸⁴ Nevertheless, we recommend that both of these approaches continue to be used by SCE researchers.

480. See discussion *supra* Part I.

481. See *supra* notes 435–41 and accompanying text.

482. See *supra* notes 435–41 and accompanying text.

483. For example, David Keith published an article for an alternate material for stratospheric aerosol injection with the intention that this would establish prior art. See David W. Keith, *Photophoretic Levitation of Engineered Aerosols for Geoengineering*, 107 PROC. NAT'L ACAD. SCI. 16428 (2010); Interview with David Keith, Gordon McKay Professor of Applied Physics and Professor of Pub. Policy, Harvard Univ. (Feb. 26, 2016).

484. 35 U.S.C. § 102 (2012).

B. TOWARD A RESEARCH COMMONS FOR SOLAR CLIMATE ENGINEERING

Rather than focus on limiting patent rights, compelling third-party access through compulsory licensing, developing patent pools, or defensive publication; we propose the formation of an SCE research commons. This would have four principal elements: (1) a framework for sharing research data; (2) a series of commitments or pledges by public and private research institutions to make patent licenses available on specific, favorable terms; (3) an internationally coordinated effort to monitor and assess emerging patents, patent applications, and trade secrets; and (4) clarification of government policies regarding the exercise of retained or march-in rights.

We believe that the early establishment of an SCE research commons is particularly important. SCE research today is dominated by researchers at public and traditional institutions who are, for the large part, not filing and enforcing patent claims and are willing to share data.⁴⁸⁵ Yet as the field matures, some research activity will likely migrate from publicly funded academic institutions and other traditional research institutions to the private sector. At such time, it would be easier to persuade corporate actors to participate in an existing research commons that is already viewed as the norm in the field, rather than to urge them to form one notwithstanding their existing R&D.

1. Research Data Sharing

Current academic SCE researchers presently appear to be willing to share research data and information arising from their research. This prevailing attitude bodes well for future collaboration. However, several measures can be taken at an early stage in order to preserve this open research environment as SCE research area increases in prominence and scope.

One such measure would be the establishment of an open technical framework for SCE data sharing. As discussed above, commons such as these can yield benefits beyond the immediate sharing and dissemination of research data.⁴⁸⁶ In particular, these mechanisms can serve to make otherwise obscure prior art available to examining patent offices around

485. *See supra* notes 115–20 and accompanying text.

486. *See generally supra* note 119 and accompanying text.

the world, thereby limiting patenting activity by external actors (e.g. PAEs) seeking to obtain and maximize monetization of patents in potentially lucrative fields.⁴⁸⁷ Such a framework would both offer researchers a convenient and uniform resource for sharing their data with the broader research community, and provide users (including researchers, policy makers, and members of the public) an accessible and open means for accessing SCE research data. As discussed in Subsection V.B.3 above, data sharing infrastructures have advanced research and facilitated collaboration in fields ranging from genetics and genomics to astronomy, earth science, and climatology.⁴⁸⁸ Such data sharing frameworks can take many forms, and the ultimate structure of such a framework, whether it is centrally managed and curated or distributed, and how its various components will interoperate, will depend on factors including availability of funding, the degree of international regulation on resulting data and the internal policies and practices of participating institutions.⁴⁸⁹ However, even with limited budgets and resources, early planning and collaboration in the area of data sharing by the relevant research community can achieve significant gains.⁴⁹⁰

While some research communities have developed highly successful data sharing frameworks independently (e.g., the BioBricks Foundation), many of the more ambitious projects in this area have been encouraged or mandated by government/charitable funding agencies (e.g., the public genomics databases established during the HGP).⁴⁹¹ Given the inherently public and international nature of SCE research, development, and possible implementation, we recommend that relevant public and private funding agencies cooperate to develop uniform data requirements for creating, maintaining, curating, indexing, annotating, and archiving SCE research. They should also establish minimal conditions for the sharing of SCE research data. At this stage, it is premature to insist on a centralized data repository for SCE research, though such centralized structures can offer significant benefits, albeit at a cost.

487. See *supra* notes 435–38 and accompanying text.

488. See *supra* Subsection V.B.3.

489. See Contreras & Reichman, *supra* note 304, at 1313.

490. *Id.*

491. See *supra* note 427.

A logical site for the development of these standards and policies could be the Working Group on Coupled Modeling of the World Climate Research Programme, a UN-affiliated body whose mission is “to foster the development and review of coupled climate models . . . includ[ing] the organisation of model intercomparisons projects aiming at understanding natural climate variability on decadal to centennial time scales and its predictability, and at predicting the response of the climate system to changes in natural and anthropogenic forcing.”⁴⁹² We also recommend that other relevant stakeholders, such as governments, scientific societies, private industry, and environmentally oriented nongovernmental organizations, be engaged in the oversight and governance of such an SCE research data sharing regime.

2. A Solar Climate Engineering Intellectual Property Pledge Community

The second element of our proposed SCE research commons is an IP pledge community. In this, SCE researchers and their institutions would commit either not to assert their SCE patents against certain implementations, or to grant licenses under favorable terms. They would also make other commitments to further open and responsible SCE research.

As discussed in Subsection V.B.2 above, such commitments or “patent pledges” have been adopted in a variety of settings from wireless telecommunications standards bodies to open source software communities to environmentally friendly technologies.⁴⁹³ Although patent pledges are forms of private action, they can be enforced under a variety of legal mechanisms, such as contract law, estoppel, and antitrust/competition law.⁴⁹⁴ They also have the benefit of global applicability, eliminating the need for each relevant jurisdiction to enact its own legislative or administrative solutions. That is, a pledge can operate on the entire global patent portfolio of the pledgor, making it inherently international.

We propose the development of a uniform IP pledge that possess the following minimum terms:

492. World Climate Research Programme, *The Working Group on Coupled Modeling (WCGSM): Overview*, <https://www.wcrp-climate.org/wgcm-overview> (last visited Feb. 22, 2016).

493. See *supra* Subsection V.B.2.

494. See Contreras, *Market Reliance*, *supra* note 408, at 482–84.

1. The pledge applies to all patents held by the pledgor that cover technologies necessary to research, develop, or implement SCE, as well as any other patents resulting from the pledgor's SCE research.
2. The pledgor commits not to assert covered patents against other pledgors in the latter's legitimate SCE R&D activities.
3. As an alternative to the above, pledgors may license their patents nonexclusively to other pledgors at reasonable royalty rates for the latter's legitimate SCE R&D activities.
4. The pledgor makes any future sales or transfers of the patent conditional upon acceptance of the pledge by the recipient.
5. The pledgor produces and makes available SCE research data in a manner consistent with international standards, such as those describe in Subsection VI.B.1, above.
6. The pledgor commits to share SCE-related data with other legitimate SCE researchers.
7. The pledgor cooperates with international efforts to monitor and assess patents related to SCE, such as those described in Subsection VI.B.3, below.
8. The pledgor submits results of SCE research to peer reviewed scientific journals, preferably with open access.
9. The pledgor commits to not retain valuable technical information regarding SCE as a trade secret.

We envision that both SCE researchers and research institutions could adopt the pledge. The former group may do so more quickly, given their apparent desire that IP not interfere with SCE R&D⁴⁹⁵ and the difficulty of institutional decision-making processes. In the longer run, a community of research institutions that have pledged would be easier to coordinate. The institutions should require that their SCE

495. See, e.g., *supra* Section III.B.

researchers abide by the IP pledge, which would more effectively bring junior and temporary researchers into the pledge's fold. Furthermore, funders and scientific publishers could also commit to support and publish only SCE research conducted by pledgors.

Significant institutional support will be necessary for launching the pledge, as well as for subsequent administration. However, public decision makers presently appear to be reluctant to engage with SCE.⁴⁹⁶ Given the present circumstances, non- and quasi-governmental scientific bodies such as the Royal Society of London, 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, may be well positioned to develop and support an IP pledge community. The Solar Radiation Management Governance Initiative, a project of the Royal Society, Environmental Defense Fund, and The World Academy of Sciences, could also play a facilitative role. There should be mechanisms to incorporate other partners, such as public funders, other public 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 greater legalization of an administrative body and the pledge community, such as through the gradually increasing involvement of national governments and intergovernmental organizations.

The second-best option of royalties for the licensing of SCE patents under the pledge (item 3 above) warrants elaboration. On one hand, we are concerned about the growth of SCE patents, particularly at the early stages of research, for a variety of reasons discussed above in Part IV. At the same time, a total prohibition on patent royalties might make the pledge unattractive and reduce incentives for innovation. This is more likely to be a concern at later developmental stages, such as potential SCE implementation by governmental actors that procure services in the private sector. Our recommendation of reasonable royalties could be a first step toward balancing these competing concerns. However, a precise determination of reasonableness may require costly litigation. Another possibility would be to subject the SCE patents held by

496. See discussion in *supra* Section V.A.

members of the pledge community to an aggregate rate cap.⁴⁹⁷ Of course, some institution, with the input of multiple stakeholders, would need to determine the cap and allocate it across the multiple patents to which it would apply. That body could be the one described in the Subsection that immediately follows.

3. International Patent Monitoring and Assessment

We have concerns regarding the potential accumulation and enforcement of patents related to SCE, given the need for widespread, expeditious research and the potential benefits of its development and possible implementation. Our concerns are especially acute with respect to the development of early, broad SCE-related patent claims, or patent claims on uncreative applications of SCE-related scientific discoveries or trivially modified natural materials (to whatever extent they are currently eligible under national patent laws). In order to address potential issues that would arise from such broad or basic patents covering key SCE technologies, methods, or products, we urge national patent offices to be vigilant in examining patent applications relating to SCE, particularly given the early stage of the field and the potential scarcity of prior art.

One important step toward this goal could be the establishment of an international SCE patent monitoring panel comprising members of relevant national and regional patent offices, supplemented by academic and industry experts drawn from both within and beyond the SCE research community. Such a panel could monitor patent filing and assertion trends in the area of SCE, and could make recommendations to governmental agencies and legislatures if patenting activity appeared to pose a threat to the responsible R&D of SCE technologies.⁴⁹⁸

This panel could also coordinate efforts to collect and make available relevant SCE prior art in order to aid national patent

497. This structure would resemble a patent pool, though it would avoid some of the restrictions imposed on pools as antitrust compliance measures. See Contreras, *Fixing FRAND*, *supra* note 477, at 75–81 (proposing “pseudo-pool” approach to fix maximum aggregate royalty caps on patents essential to certain technical standards).

498. Of course, membership on this panel should not be used by academic or industrial SCE researchers to gain confidential early knowledge of their competitors’ patent applications. Thus, care would be needed to address potential conflict of interest issues for the members of such a panel.

offices in examining SCE patent applications, so as to restrict granted claims to truly novel and non-obvious inventions. Engaging the broader SCE research community in documenting their tacit and codified knowledge for ready use by patent offices could also be useful.⁴⁹⁹ As a counterpart, the panel could request the input of SCE researchers to help review published patent applications in the SCE field, much as the software community was invited to inspect and offer relevant prior art in response to software-based inventions in the U.S. “peer to patent” pilot program.⁵⁰⁰

Finally, to the extent that data sharing is required as part of the SCE research commons, the proposed panel could also serve to monitor data sharing and use compliance and to adjudicate disputes regarding data sharing violations.⁵⁰¹

4. Clarifying the Government Role in Using and Assuring Access to Patented Technologies

If, notwithstanding the implementation of proposals such as those described above, problems develop with regard to SCE data sharing or access to patent rights, government efforts to exercise powers to compel greater sharing or access may come into play. This is also important to assure the public that no private actor will retain exclusive rights to reduce climate change and its risks through SCE. Accordingly, the final element of our proposal is for interested governments to convene multi-stakeholder meetings to begin to detail and publish the criteria under which they would exercise such governmental use, march-in, compulsory licensing, and other powers. A particular possibility is a set of “best practices” for when and how governments might exercise (1) their funding powers to compel greater sharing of data; (2) their existing rights or powers to use government-funded or privately funded patented technologies themselves (or through contractors) with or without compensation to rights holders; and (3) their authority to impose additional restrictions on government-

499. Such approaches have been used with varying degrees in, for example, the area of computer software.

500. *Peer to Patent*, N.Y. L. SCH., <http://www.peertopatent.org> (last visited Nov. 10, 2016).

501. NIH has adopted a similar policing and enforcement role with respect to genomic data that is required to be shared by researchers, though critics have questioned the effectiveness of the agency’s efforts in this respect. See Contreras, *Leviathan in the Commons*, *supra* note 310, at 17.

funded patent rights or to march in to correct problems with access to or costs of using the patented technologies for research, development, or implementation.⁵⁰² Because patent holders will likely seek rights in multiple jurisdictions, and because SCE technologies may have only limited private uses, such coordination of government approaches will be critical. Further, specifying in advance the criteria for the exercise of such powers may reduce uncertainties for private researchers and investors and actually expand efforts and funding directed towards this important technological field. As one of the authors has previously noted, funding recipients then should understand the conditions on which clarified march-in rights would be exercised

and thus should (or could) either have avoided accepting the terms of the deal or have avoided creating the triggering conditions. For this reason, the exercise of march-in rights should not generate concerns similar to regulatory takings of constitutionally protected property, as there would be no 'reasonable, investment-backed expectation' that the government would not engage in such action.⁵⁰³

C. ADDITIONAL POLICY PROPOSALS

This article's proposal focused on a research commons for SCE consisting of data sharing, patent pledging, patent monitoring, and governmental coordination. These proposals could likely occur without the need for national legislation.⁵⁰⁴ Below, we also recommend that scholars and policy makers consider two other potential courses of action related to IP policy. Because these would likely require some changes to national legislation (or at least significant changes to current judicial and administrative approaches), and given potential political obstacles to achieving them, we offer these proposals separately from the research commons identified above.

First, although we do not advocate the wholesale exclusion of SCE technologies from patent eligibility, we support the strengthening and broadening of exemptions from patent infringement for scientific research, technical interoperability, and reverse-engineering.⁵⁰⁵ Though some countries such as

502. See, e.g., Sarnoff, *supra* note 342, at 349–56 (recommending creation of retained rights to assure research and humanitarian uses, presumptions of non-exclusive licensing, and clarification of march-in criteria).

503. *Id.* at 356.

504. See *supra* Subsection VI.A.1.

505. See Sarnoff, *The Patent System and Climate Change*, *supra* note 342, at 344–48.

Belgium and the United Kingdom recognize a broad exemption from patent infringement for scientific research using patented inventions, even when commercially motivated,⁵⁰⁶ the 2002 appellate court decision in *Madey v. Duke University* severely eroded this doctrine in the United States.⁵⁰⁷ Accordingly, except for a small number of exceptions,⁵⁰⁸ basic scientific research carried out at academic laboratories in the United States can infringe patents. Given the pressing need for global research and coordination in the field of SCE, we recommend that a more robust research exemption be recognized either judicially or legislatively in the United States and other countries that do not currently recognize such an exemption.

Second, although patents are used as a means to incentivize investment in research and technological development, the public good nature of SCE technologies suggests that the financial incentives for private action are likely to be significantly lower than social returns to public welfare from SCE inventions.⁵⁰⁹ This would especially be the

506. See, e.g., Belgian Patent Act, art. 28, § 1(b) (enacted Apr. 25, 2005), <http://www.ejustice.just.fgov.be/cgi/summary.pl>; Geertrui Van Overwalle, *The Implementation of the Biotechnology Directive in Belgium and its After-Effects. The Introduction of a New Research Exemption and a Compulsory Licence for Public Health*, 37 INT'L REV. INTELL. PROP. & COMPETITION L. 889, 906–08 (2006); see generally Judith L. Curry & Bruce E. O'Connor, *University Research: A New Defense Under the Patent Law*, 12 J. INTELL. PROP. L. 29 (2004) (stating that broad patent law exceptions for academic institutions, such as the *experimental use exception* and the *research exemption*, regarding innovative developments are starting to be called into question by courts).

507. See *Madey v. Duke Univ.*, 307 F.3d 1351, 1362 (Fed. Cir. 2002) (holding that research activities at Duke University could infringe a former researcher's patent given the potentially commercial nature of Duke's research enterprise, its need to raise funds through tuition and government grants, and the like); see also Amy Yancey & C. Neal Stewart, Jr., *Are University Researchers at Risk for Patent Infringement?* 25 NATURE BIOTECHNOLOGY 1225 (2007).

508. Two types of research are generally exempt from patent infringement in the United States. First, experimentation conducted in furtherance of regulatory submissions for drugs and veterinary products is exempt from patent infringement. 35 U.S.C. § 271(e) (2012). Second, because state governments may not be sued in U.S. federal courts, research activities conducted by state universities are generally believed to be immune from claims for patent infringement damages (which are purely federal claims), although injunctive relief may potentially be obtained. See *Fla. Prepaid Postsecondary Educ. Expense Bd. v. Coll. Sav. Bank*, 527 U.S. 627 (1999).

509. See generally Mark A. Lemley & Brett Frischmann, *Spillovers*, 107 COLUM. L. REV. 257 (2006) (arguing that patented technology can provide more social welfare for the public, by a significant factor, than is gained in the private sphere by protecting patents).

case with the widespread adoption of an IP pledge that limits royalties. It is consequently possible that alternative mechanisms such as prizes and tax incentives could also be leveraged to help achieve such competition and technological advancement in this area.⁵¹⁰ We therefore urge policymakers to explore such avenues of promoting SCE R&D. Further, if governments make a clearer commitment to procuring such technologies if they prove safe, effective, cost-effective, and politically acceptable, that commitment will likely attract substantially more private capital to this field much more quickly. And for global climate change, time is of the essence.

VII. CONCLUSION

SCE appears to offer substantial potential for averting the most dire consequences of global climate change. While the emerging SCE research community has not yet experienced significant disruption due to IP aggregation or litigation, the potential for such effects exists,⁵¹¹ particularly if the actual use of SCE technologies becomes more likely. The current, early state of R&D of SCE as well as the present absence of IP claims provide a unique opportunity to create norms and institutions to help assure that the R&D of these important—but risky and controversial—technologies proceed in a manner that supports the common good. We therefore encourage other scholars and policy makers to take up the call to consider, refine, and generate a research commons in SCE at the earliest possible opportunity, before substantial problems arise that could now be avoided.

510. See *supra* notes 342–45 and accompanying text; see also Davies, *supra* note 256.

511. See Schofield, *supra* note 294, at 592.