USING LEGAL PRINCIPLES TO GUIDE GEOENGINEERING DEPLOYMENT

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TABLE OF CONTENTS

I. INTRODUCTION ……………………………………………...2

II. HUMANS ARE CAUSING SEVERE DAMAGE TO THE CLIMATE, BUT GEOENGINEERING CAN HELP AVOID THE WORST CONSEQUENCES OF CLIMATE CHANGE....3

A. Severe Climate Change Is Unavoidable………………..4

B. Climate Engineering Can Provide Benefits That Other Responses to Climate Change Cannot…………...……..7

C. The Risks Associated with Geoengineering Exceed Those of Other Responses to Climate Change…………9

III. SEVERAL LEGAL PRINCIPLES CAN GUIDE DECISIONS TO DEPLOY GEOENGINEERING TECHNOLOGIES……..12

A. The Benefits of a Technology Should Outweigh Its Risks…………………………………………….…13

1. The technology should provide an effective remedy…………………………….…….13

2. The benefits of a technology should outweigh its risks………………………………………..14

3. Precaution should guide decisions involving scientific uncertainty……………………….....16

B. We Should Consider Alternatives to Proposed Actions……………………………………………...21

C. We Should Avoid Creating a Moral Hazard………….24

D. We Should Minimize Harm to Future Generations…...25

E. We Should Avoid Disparate Regional Impacts………27

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F. We Should Seek to Preserve the Natural State of the Environment……………………………………………..29

G. We Should Avoid Irreversible Consequences……..…32

H. We Should Be Able to Contain the Effects of a Technology…………………………………….....…...32

I. We Should Seek Solutions That Fully Resolve Problems……………………………………………34

IV. APPLICATION OF THESE PRINCIPLES CAN GUIDE DECISIONS TO DEPLOY CLIMATE ENGINEERING…...35

A. Some General Conclusions Concerning All Geoengineering Methods…..………………………....35

1. Determining the objective for intervening in the climate……………..………………………....36

2. Certain principles apply equally – if at all – to all technologies……………………………….38

3. Determining a baseline for comparison……....41

B. Decision Making with the Principles…………...……43

C. Application of These Principles Suggests That Some Geoengineering Solutions Might Be More Acceptable Than Others…………………………….....…………47

1. Particle injection to cool to pre-industrial levels……………………………………….49

2. Particle injection to constrain warming……....52

3. Cloud brightening and cloud thinning………..55

V. CONCLUSION……………………………………………..60

I. INTRODUCTION

Climate change will be unavoidable, long-lasting, and potentially catastrophic. While mitigation is critical, it can no longer enable us to avoid many of the consequences of climate change. Not surprisingly, many nations and their scientists are beginning to study the feasibility of engineering the climate. Indeed, earlier this year the United States' National Research Council concluded that the likelihood that society will need to deploy some form of geoengineering is becoming increasingly likely.[1] Nevertheless, no one has begun determining what principles society should apply when deciding whether to deploy geoengineering.

This article identifies and reviews legal concepts that can inform this decision. Then, it determines which legal principles should be used and which can be discarded. Next, it applies decision-making theories to determine the best approach to utilize these principles. With this background, it proposes a prioritization of the principles – cost-benefit analysis, consideration of alternatives, intergenerational equity, regional equity, reversibility of consequences, and containment of effects. Finally, it demonstrates the value of the principles by applying them to some of the most promising climate engineering technologies to determine, based upon present information, which would be the most acceptable to deploy.

II. HUMANS ARE CAUSING SEVERE DAMAGE TO THE CLIMATE, BUT GEOENGINEERING CAN HELP AVOID THE WORST CONSEQUENCES OF CLIMATE CHANGE.

Human-caused emissions of greenhouse gases are causing a rapid warming of the planet. Even though the planet is nearing significant climate tipping points, these emissions are on track to continue for decades. Their consequences, however, will last for

[1] National Research Council, CLIMATE INTERVENTION: REFLECTING SUNLIGHT TO COOL EARTH ("NRC Report") 5 (2015).

centuries. To minimize these consequences, society is beginning to consider engineering the climate. Climate engineering presents the promise of minimizing climate change's worst consequences. Many argue, however, that the consequences of these technologies will far exceed any benefits they might provide. Thus, legal principles need to be identified that can assist decision makers in determining whether to deploy these technologies.

A. Severe Climate Change Is Unavoidable.

Emissions of greenhouse gases have increased significantly since the beginning of the Industrial Revolution. Indeed, the concentration of several greenhouse gases has more than doubled since pre-industrial times.[2] More distressing, the increase in the most prominent of these gases – carbon dioxide – is accelerating. In 2013, the annual increase in carbon dioxide was the largest in three decades.[3]

At their current rate, these emissions will cause significant climate change. A number of planetary systems are already demonstrating the effects. For instance, 2014 was the hottest year on record.[4] In addition, the three hottest years on record (2014, 2010, and

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[2] World Meteorological Organization ("WMO"), WMO Greenhouse Gas Bulletin 1, September 9, 2014. Specifically, since 1750, the concentration of carbon dioxide has increased 142%, nitrous oxide by 121%, and methane by 253%. *Id*.

[3] *Id*.

[4] National Oceanic and Atmospheric Administration ("NOAA"), Global Analysis - December 2014, available at http://www.ncdc.noaa.gov/sotc/global/2014/12. Not only was 2014 the hottest year recorded, the increase in temperature also set a record. In 2014, the planet warmed by 0.69°C (1.24°F), which easily surpassed the previous records of 2005 and 2010. *Id*.

2005) all occurred during the past ten years.[5] Global mean sea level has risen steadily since 1900, and this rise is accelerating.[6] Ocean acidification is measurable and occurring at the fastest rate in the past 300 million years.[7]

The consensus of the international community has been that we must hold global warming below two degrees Celsius to avoid "dangerous climate change."[8] This goal, however, is now "patently unrealistic."[9] Even more troubling, scientists now project the impacts of a 2°C rise to be worse than anticipated. Consequently, scientists now identify such an increase as representing "dangerous" or "extremely dangerous" climate change.[10] Furthermore, scientists calculate that, once we curtail greenhouse gas emissions, planetary warming will continue to increase for decades.[11] Then, the climate will remain at its new level for at least 1,000 years.[12]

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[5] Justin Gillis, 2014 Breaks Heat Record, Challenging Global Warming Skeptics, NEW YORK TIMES, January 16, 2015, available at http://www.nytimes.com/2015/01/17/science/earth/2014-was-hottest-year-on-record-surpassing-2010.html?_r=0 (quoting Tefan Rahmstorf, head of earth system analysis at the Potsdam Institute for Climate Impact Research).

[6] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (" IPCC"), CLIMATE CHANGE (" Fifth Assessment Report") 409 (2013).

[7] WMO, *supra* note 2 at 4.

[8] Wil Burns, Introduction: Climate Change Geoengineering, Carbon & Climate Law Review 87 (2013).

[9] *Id*. Indeed, the United Nations Environment Programme Emissions Gap Report notes that current emission trends and commitments project warming reaching 3.5°C to 5°C by 2100. The World Bank, TURN DOWN THE HEAT 1 (2013).

[10] Kevin Anderson & Alice Bows, Beyond 'Dangerous' Climate Change: Emission Scenarios for a New World, PHIL. TRANS. R. SOC'Y A (2011) 369, 20-44, 23.

[11] H. Damon Matthews & Ken Caldeira, "Stabilizing climate requires near-zero emissions," GEOPHYSICAL RESEARCH LETTERS, 27 Feb. 2008, at 1. The IPCC estimates that if the composition of the atmosphere were to be held constant, the global temperature would still rise by up to 0.9° C by the end of the 21st century. IPCC, *supra* note 6 at 822.

[12] Susan Solomon, et al, Irreversible Climate Change Due to Carbon Dioxide Emissions, PNAS 1704-1709, 1704, February 10, 2009.

Thus, our emissions are likely to cause two problems. First, they will alter the planet's climate profoundly. Second, this change will last for generations. Thus, mitigation alone can no longer avert significant climate consequences, nor is mitigation capable of returning the climate to its previous state in less than a millenia. To address these problems, scientists have begun considering climate engineering.

Climate engineering[13] identifies a broad range of methods and technologies intended to alter the Earth's climate system to counter deliberately the impacts of climate change.[14] Geoengineering techniques fall into two broad categories.[15] The first, identified as solar radiation management (SRM),[16] would increase the reflection of sunlight to cool the planet.[17] The second, labeled carbon dioxide removal (CDR), would remove CO_2 from the atmosphere.[18] This article will focus on the former.

SRM technologies reflect a small percentage of inbound light and heat from the sun back into space.[19] They cover a broad range of methods. Surface-based techniques include painting roofs white,

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[13] Numerous terms besides "climate engineering" have been used to refer to these efforts, including "geoengineering," which appears most frequently. More recently, the NRC used the term "climate intervention," reasoning that it connoted "an action intended to improve a situation," while "climate engineering" implied a greater level of precision than possible. NRC Report at x. This article will use these terms interchangeably.

[14] IPCC, Fifth Assessment Report, Annex I: Glossary ("IPCC Glossary") 23 (2014).

[15] The Royal Society, the United Kingdom's national academy of sciences, produced a seminal analysis of geoengineering that utilized this distinction. *Id*. Subsequent reports (including those prepared by a House subcommittee, the NRC, GAO, and the IPCC) have followed this dichotomy.

[16] Another term used, most prominently in the NRC Report, is "albedo modification." NRC Report, *supra* note 1 at 2.

[17] IPCC, Fifth Assessment Report, *supra* note 6 at 91.

[18] NRC Report, *supra* note 1 at 2.

[19] ROYAL SOC'Y, GEOENGINEERING THE CLIMATE: SCIENCE, GOVERNANCE AND UNCERTAINTY 14 (2009).

planting more reflective crops, or covering desert or ocean surfaces with reflective materials.[20] Atmospheric methods would inject aerosol particles into the atmosphere[21] or increase the reflectivity of clouds (by adding sea salt or other materials to whiten clouds).[22] An alternative technology would thin cirrus clouds to allow greater amounts of solar radiation to leave the atmosphere.[23]

B. Climate Engineering Can Provide Benefits That Other Responses to Climate Change Cannot.

Climate engineering has several advantages over mitigation or adaptation. First, it will cost a fraction of those methods. For instance, at least two geoengineering methods – stratospheric aerosols and cloud whitening– each could cost less than $10 billion per year.[24] When

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[20] Peter J. Irvine, Andy Ridgwell, & Daniel J. Lunt, Climatic Effects of Surface Albedo Geoengineering, 116 JOURNAL OF GEOPHYSICAL RESEARCH D24112, 2 (2011).
[21] See *infra* section IV.C.
[22] See *infra* section IV.C.3.
[23] *Id*.
[24] Scott Barrett, The Incredible Economics of Geoengineering, 39 ENVTL. & RES. ECON. 45, 49 (2008). The Panel on Policy Implications of Greenhouse Warming calculated that adding aerosol dust to the stratosphere would cost just pennies per ton of CO_2 mitigated. In a 1994 estimate based upon this analysis, Nordhaus concluded that offsetting all greenhouse gas emissions today would cost about $8 billion per year. *Id*. *See also* James Temple, Cloud Brightening: Theory to Prototype, SAN FRANCISCO CHRONICLE, January 5, 2013, available at http://www.sfgate.com/science/article/Cloud-brightening-theory-to-prototype-4170478.php (cloud brightening using seawater projected to cost as low as $2.5 billion annually). Even persons skeptical of such calculations have acknowledged that the costs of such systems would be "trivial" compared to mitigation approaches. Barrett, *supra* note 24 at 49.

compared to the trillion dollars that mitigation could cost annually,[25] such an alternative is essentially "costless."[26]

Geoengineering could also be much easier to enact. Mitigation requires the compliance of billions of consumers and unprecedented international cooperation.[27] Climate engineering, on the other hand, could be implemented by a single state, or even by a single (albeit well-financed) individual.[28]

In addition, SRM could take effect in a matter of months.[29] A major advantage of many SRM technologies is that they may be the only means to reduce the global temperature almost immediately, should that become necessary to avert a climate emergency or to buy time to more fully implement mitigation.[30] Thus, to produce a rapid reduction in the

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[25] Justin McClellan, David W. Keith, & Jay Apt, Cost Analysis of Stratospheric Albedo Modification Delivery Systems, ENVIRON. RES. LETT. 7 (2012) at 6 (estimating that by 2030 the annual cost of mitigation will range from $200 billion to $2 trillion).

[26] Barrett, *supra* note 24 at 49. Another estimate is that SRM would have a marginal cost of approximately 1/10,000th of the cost of mitigation. Alan Carlin, Why a Different Approach Is Required If Global Climate Change Is to Be Controlled Efficiently or Even at All, 32 WM & MARY ENVTL. L & POL'Y REV. 685, 739 (2008).

[27] Barrett, *supra* note 24 at 49. For instance, merely stabilizing CO_2 levels would require cutting emissions by 60-80%; nevertheless, emissions have risen approximately 20% since the adoption of the Framework Convention on Climate Change. *Id*.

[28] William C.G. Burns, Climate Geoengineering: Solar Radiation Management and its Implications for Intergenerational Equity, 4 STAN J.L. SCI. & POL'Y 37, 46, n.50 (2011), available at https://docs.google.com/viewer?a=v&q=cache:_QbCDQUwX7sJ:www.stanford.edu/group/sjlsp/cgi-bin/users_images/pdfs/61_Burns%2520Final.pdf+burns+climate+geoengineering&hl=en&gl=us&pid=bl&srcid=ADADGEESj--1TMdnkdao8yxgNDqMvG6D1q59ZfHrQFJReE7YC3hUiKpXRZqOlhuL-UNsnm16du-bhscJE7UzQQxKwNDh6ptuf2yL17tOEBLLZfUeJDrIBWI3uLCra0k8J54ZE6udX9Mn&sig=AHIEtbT4jvvTHU7d-LX204XM7NwQ4Q8eHQ. The related risk is that a rogue nation or group could decide unilaterally to engineer the climate. Barrett, *supra* note 24 at 46.

[29] Barrett, *supra* note 24 at 47.

[30] IPCC, *supra* note 6 at 91, 96.

amount of atmospheric carbon and its consequences, climate engineering is the only choice.

C. The Risks Associated with Geoengineering Exceed Those of Other Responses to Climate Change.

Despite the advantages of climate engineering, these technologies also involve significant risks. Scientists recognize several potential risks, some that might produce global consequences, others that might be more regional in effect. For instance, aerosol methods relying upon sulfate particles might trigger acid rain, which harms fish, plant, and, indirectly, bird populations;[31] drops in global precipitation levels;[32] and depletion of the ozone layer.[33] Albedo modification may impair ecosystem productivity from reduced photosynthesis.[34]

Another potential consequence arising from SRM involves the "termination" effect.[35] Since SRM will merely provide a cooling effect without reducing the amount of carbon in the atmosphere,[36] the atmosphere is still subject to warming if we discontinue the SRM

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[31] Ben Kravitz, et al, Sulfuric Acid Deposition From Stratospheric Geoengineering with Sulfate Aerosols, JOURNAL OF GEOPHYSICAL RESEARCH 1, July 28, 2009. Sulfur is being considered in part because it is the element released by volcanoes, upon which this method is based. Philip J. Rasch, et al, An Overview of Geoengineering of Climate Using Stratospheric Sulphate Aerosols, 366 PHIL. TRANS. R. SOC'Y A, 4007–4037, 4009 (2008).
[32] Bryan Walsh, Can Geoengineering Help Slow Global Warming?, Time, August 18, 2009, available at http://www.time.com/time/health/article/0,8599,1916965,00.html
[33] Simone Tilmes, et al, Impact of Geoengineered Aerosols on the Troposphere and Stratosphere, JOURNAL OF GEOPHYSICAL RESEARCH, Vol. 114, D12305 (2009) at 2.
[34] William Daniel Davis, What Does "Green" Mean?: Anthropogenic Climate Change, Geoengineering, And International Environmental Law, 43 GEORGIA LAW REVIEW 901, 923 (2009).
[35] Burns, *supra* note 28 at 47. This effect results from the accumulation of greenhouse gases during the period that the SRM technology was applied. *Id*.
[36] Barrett, *supra* note 24 at 47.

technology. Scientists calculate, however, that the planet would warm rapidly upon a sudden cessation of SRM.[37] If an SRM technology is stopped abruptly, the resulting re-warming could occur up to 20 times faster than the current warming rate of 0.2°C per decade.[38] Unfortunately, because of the inability of natural systems to adapt to rapid change, the rate of change of the climate is more disruptive than the actual climate level.[39] Scientists thus project that at a warming rate of 0.3°C per decade only 30% of all impacted ecosystems would be able to adapt.[40] Thus, because of carbon's long atmospheric lifetime, to avoid this termination effect, SRM techniques might need to be perpetuated for a millennium.[41]

In addition to these potential global consequences, climate engineering methods may also cause a number of localized effects. Since SRM will not reduce the atmospheric carbon level, the resulting atmosphere may be characterized by reduced levels of precipitation. Lower precipitation may particularly impact East and Southeast Asia, Africa, and the Amazon and Congo valleys. This may undermine the food security of two billion people.[42] Reduced precipitation may also severely impact Africa and large portions of Asia.[43]

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[37] Brovkin, et al, Geoengineering Climate by Stratospheric Sulfur Injections: Earth System Vulnerability to Technological Failure, 92 Climatic Change (2009) 92:243–259, 254.
[38] Burns, *supra* note 28 at 47.
[39] Alan Robock, Stratospheric Aerosol Geoengineering, 38 ISSUES IN ENVIRONMENTAL SCIENCE AND TECHNOLOLGY 162-185, 171-72 (2014).
[40] Burns, *supra* note 28 at 48.
[41] Antti-Ilari Partanen, Direct and Indirect Effects of Sea Spray Geoengineering and the Role of Injected Particle Size, JOURNAL OF GEOPHYSICAL RESEARCH, Vol. 117, Issue D2, 15 (2012).
[42] Burns, *supra* note 28 at 40.
[43] *Id*.

Although many believe the risks of geoengineering are sufficient to reject it as a response to climate change,[44] a number of countries have already initiated climate engineering research.[45] Indeed, China, the largest greenhouse gas emitter,[46] has identified geoengineering among its Earth science research priorities.[47] Similarly, India, another developing country investing heavily in coal power plants,[48] also is engaging in geoengineering research.[49] Russia not only supports geoengineering research,[50] it actually conducted one of the first SRM field experiments.[51]

Maybe most importantly, we may feel a moral obligation to engineer the climate. Climate change will most significantly impact

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[44] Alan Robock, 20 Reasons Why Geoengineering May Be a Bad Idea ("20 Reasons"), BULLETIN ATOM. SCI., 64:14-18, 17-18 (2008). Another objection commonly raised, that geoengineering will create a moral hazard, is discussed more fully section IV.A.2.

[45] Anthony E. Chavez, A Napoleonic Approach to Climate Change: The Geoengineering Branch, 5 WASH. & LEE J. CLIMATE & ENV'T 93, 123 (2014). These nations include the United Kingdom, France, Germany, and Norway. *Id*.

[46] Steven Mufson, China's Pledge to Cut Greenhouse Gases Eliminates Excuse for Other Nations, THE WASHINGTON POST (November 12, 2014), available at http://www.washingtonpost.com/business/economy/chinas-pledge-to-cut-greenhouse-gases-eliminates-excuse-for-other-nations/2014/11/12/5a22b0de-6a8f-11e4-a31c-77759fc1eacc_story.html.

[47] Clive Hamilton, Why Geoengineering Has Immediate Appeal to China, THE GUARDIAN (March 22, 2013), available at http://www.theguardian.com/environment/2013/mar/22/geoengineering-china-climate-change.

[48] Candace Dunn, India Is Increasingly Dependent on Imported Fossil Fuels as Demand Continues to Rise, U.S. E.I.A. (August 14, 2014), available at http://www.eia.gov/todayinenergy/detail.cfm?id=17551 (India is currently the third-largest global coal producer, consumer, and importer of coal, with demand increasing by 7% per year over the past five years).

[49] Christopher J. Preston, Solar Radiation Management and Vulnerable Populations: The Moral Deficit and its Prospects, ENGINEERING THE CLIMATE: THE ETHICS OF SOLAR RADIATION MANAGEMENT 82 (2012).

[50] Martin Lukacs, Suzanne Goldenberg & Adam Vaughan, Russia Urges UN Climate Report to Include Geoengineering, THE GUARDIAN, September 19, 2013, available at http://www.theguardian.com/environment/2013/sep/19/russia-un-climate-report-geoengineering.

[51] Jeremy Hsu, First Geoengineering Field Trial Carried Out in Russia, POPULAR SCIENCE (2009), available at http://www.popsci.com/technology/article/2009-12/first-geoengineering-field-trial-carried-out-russia-0.

those populations least able to adapt,[52] and climate engineering may provide one of the few alternatives to minimize this suffering.[53] The possibility that it could provide a meaningful reduction in climate risks for the most vulnerable persons and ecosystems[54] may render it too compelling to ignore.

For all of these reasons and others, the likelihood that climate engineering will be seriously considered is growing.[55] Thus, regardless of any objections that may be raised, we need to consider a principled approach to evaluate whether to engineer the climate.

III. SEVERAL LEGAL PRINCIPLES CAN GUIDE DECISIONS TO DEPLOY GEOENGINEERING TECHNOLOGIES.

To determine whether we should deploy geoengineering, we need to identify a set of principles with which to make such a decision. Legal doctrines and statutory approaches suggest several considerations which might be included. While they may not all be helpful or dispositive, they nevertheless can inform this process. By applying such

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[52] Scientists anticipate that the impacts of climate change will "fall largely and disproportionately on the developing world." Tiffany T.V. Duong, When Islands Drown: The Plight of "Climate Change Refugees" and Recourse to International Human Rights Law, 31 J. of INTERNATIONAL LAW 1239, 1241 (2014).

[53] Chris Caseldine, So What Sort of Climate Do We Want? Thoughts on How to Decide What Is 'Natural' Climate, THE GEOGRAPHIC JOURNAL 2, 7 (2014).

[54] David Keith, Climate Engineering, No Longer on the Fringe, February 18, 2015, available at https://www.seas.harvard.edu/news/2015/02/climate-engineering-no-longer-on-fringe.

[55] NRC Report, *supra* note 1 at 5; *see also* Andy Ridgwell, Chris Freeman & Richard Lampitt, Geoengineering: Taking Control of Our Planet's Climate?, 370 PHIL. TRANS. R. SOC. A 4163-4165, 4163 (2012) ("Concerns about the likely consequences of continuing climate change have greatly increased interest in geoengineering").

principles, we can provide this determination with a principled basis and replicable structure.[56]

The following legal principles may help guide the decision to deploy geoengineering:

A. The Benefits of a Technology Should Outweigh Its Risks.

Three possible principles – the effectiveness of a remedy, cost-benefit analysis, and the precautionary principle – overlap. The first two consider the effectiveness of a solution, and the latter two weigh those benefits against its risks. Initially, this article will review each separately. In Section III, it will consider how best to treat these overlapping principles.

1. The technology should provide an effective remedy.

The law of remedies is largely conventional and what constitutes a full or adequate remedy is the same.[57] A remedy should be effective – it should leave a party better off than it would have been without it.[58] While courts will not accept wholly ineffectual remedies,[59] they will, however, not require a perfect remedy. Courts accept imperfect remedies, and they will even order remedies that they know will be

[56] Doggett v. United States, 505 U.S. 647, 669, (1992) (O'Connor, dissenting) (recognizing that the multi- factor test established in Barker v. Wingo, 407 U.S. 514 (1972), sets forth a number of relevant factors that provide the inquiry with some structure).
[57] Richard H. Fallon, Jr. , & Daniel J. Meltzer, New Law, Non-Retroactivity, and Constitutional Remedies, 104 HARV. L. REV. 1731, 1779 (June 1991).
[58] Richard H. Fallon, Jr., The Linkage between Justiciability and Remedies – and their Connections to Substantive Rights, 92 VA. L. REV. 633, 652 (2006).
[59] *Id*.

imperfect.[60] Indeed, under certain circumstances a court will sacrifice remedial effectiveness for other considerations. Specifically, it will balance the net benefits against the net societal costs.[61]

2. The benefits of a technology should outweigh its risks.

The balancing of consequences is a strategy employed by policymakers to determine whether the implementation of a technology will have outweighing consequences. This approach derives from risk analysis. Under this approach, if the comparative risks of an action are low, then it will be readily selected.[62] If associated risks are high, then the decision maker should weigh the consequences thoroughly.[63]

Since 1990,[64] environmental policymakers have widely used comparative risk analysis to assess the risk of implementing new technology impacting the environment.[65] Comparative risk analysis is a blend of three principles. First, sound environmental policy making is analytic, rather than political.[66] Second, environmental risk is measured in terms of expected losses, for example, the expected loss of habitat and ecosystems.[67] Third, the different risks must be reduced to a common

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[60] Paul Gewirtz, Remedies and Resistance, 92 YALE L.J. 585, 590-91 (March 1983).
[61] *Id*. at 591.
[62] Matthew L. Beran, The Proportionality Balancing Test Revisited: How Counterinsurgency Changes "Military Advantage, ARMY LAW 4 (August 2010).
[63] *Id*. at 3.
[64] Donald T. Hornstein, *Reclaiming Environmental Law: A normative critique of comparative analysis*, 92 COLUM. L. REV. 562, 564 (1992).
[65] *Id*. at 563.
[66] *Id*. at 585.
[67] *Id*.

metric.[68] The risk analysis must be standardized in quantitative terms and be uniform; different meanings of particular risks should be avoided. The comparative risk analysis approach is a reasonable approach to risk assessment.[69] It generalizes and quantifies the risks associated with implementing new technologies for the wellbeing of our environment.[70]

An important consideration when weighing future alternatives regards valuation. Cost benefit analysis typically discounts future costs and benefits to their present value.[71] Discounting, however, creates specific problems when applied to environmental issues. First, since it typically weighs present cost against future benefits, it usually produces a preference for present action over deferred benefits.[72] Second, and more distressing, it could suggest that the health, indeed, the lives, of present persons are more valuable than those of future generations.[73]

As long as the potential benefits outweigh the potential losses,

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[68] *Id*.

[69] *Id*. at 564. Scientists studying one of the climate engineering methods, SRM, supported a balancing approach when applying a different line of analysis. Keith and MacMartin considered the usefulness of a Pareto-optimal analysis. David W. Keith & Douglas G. MacMartin, A Temporary, Moderate, and Responsive Scenario for Solar Geoengineering 4 (2014), available at http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0CCMQFjAB&url=http%3A%2F%2Fwww.cds.caltech.edu%2F~macmardg%2Fpubs%2FKeith-MacMartin-Scenario.pdf&ei=fJnBVMjyOuOasQTerIKQCA&usg=AFQjCNG5QlIIHRKsK07PU-SBs1OeavU3mg&bvm=bv.83829542,bs.1,d.eXY. Keith and MacMartin concluded that with SRM deployment some regions may always be worse off with heightened use of SRM, thus suggesting that the Pareto-improving amount of SRM would be zero. Recognizing that nearly every policy decision will make some people worse off, they concluded that approaches that fall between global and Pareto-optimality serve as better guides to policy. Id. at 5. In other words, the best approach would balance between these two considerations.

[70] Homstein, *supra* note 64 at 564.

[71] Jeffrey M. Gaba, Environmental Ethics and Our Moral Relationship to Future Generations: Future Rights and Present Virtue, 24 COLUM. J. ENVTL. L. 249, 269 (1999).

[72] *Id*.

[73] *Id*. To the extent this implicates an intergenerational conflict, this is addressed *infra* at III.D.

the public tends to perceive these losses as acceptable.[74] Decision makers should make decisions based on the potential for excessive losses when implementing a particular technology.[75] If the consequence is inconceivably large and the benefit is small, then we should decide against implementing that action. A new technology should not have excessive consequences which will harm the environment.[76]

3. Precaution should guide decisions involving scientific uncertainty.

Most of us were cautioned "better safe, than sorry" as children; this simple advice is a valid summary of the underlying theme of the precautionary principle.[77] The precautionary principle applies to activities with potential but unascertained risks of serious or irreparable harm. When an activity presents such a risk, the precautionary principle dictates postponement of the activity until more information about the risk is gathered.[78] Regarding environmental policy, the precautionary principle promotes placing a higher value on human health and environmental integrity over activities and technological advances

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[74] Donald A. Dripps, *Rehabilitating Bentham's Theory of Excuses*, 10 TEX. L. REV. 383, 388 (2009). This approach will help policymakers when making the decision to deploy new technologies. Decision makers also need to consider incidental repercussions, which arise when the resulting consequences are significant, but small enough that the benefits still outweigh the losses. Beran, *supra* note 62 at 3.
[75] *Id*.
[76] *Id*.
[77] Kenneth L. Mossman & Gary E. Marchant, *The Precautionary Principle and Radiation Protection*, 13 RISK: HEALTH SAFETY & ENV'T 137, 137 (Spring 2002).
[78] Frank B. Cross, Paradoxical Perils of the Precautionary Principle, 53 WASH. & LEE L. REV. 851, at 851 (1996).

carrying potential risks of serious or irreparable harm.[79] The absence of complete scientific certainty regarding the potential risks of an activity should not affect the decision to postpone the activity.[80]

The precautionary principle applies so well to environmental policy considerations because the issues typically involve complex questions that scientific studies have not fully resolved.[81] In a sense, the precautionary principle encourages those making decisions to err on the side of caution when considering actions where the potential adverse effects on human health and the environment are unknown.[82]

The precautionary principle first appeared in 1969 in the Swedish Environmental Protection Act, which required parties to

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[79] John S. Applegate, The Taming of the Precautionary Principle, 27 WM. & MARY ENVTL. L. & POL'Y REV. 13, 13 (2002) ("At its core, the precautionary principle embodies two fundamental regulatory policies: anthropogenic harm to human health and the environment should be avoided or minimized through anticipatory, preventive regulatory controls; and, to accomplish this, activities and technologies whose environmental consequences are uncertain but potentially serious should be restricted until the uncertainty is largely resolved.").

[80] Elizabeth Fisher, Judith S. Jones, & René von Schomberg. IMPLEMENTING THE PRECAUTIONARY PRINCIPLE : PERSPECTIVES AND PROSPECTS. Cheltenham, UK: Edward Elgar Publishing, 2006. eBook Collection at 2 (EBSCOhost) *available at* http://eds.a.ebscohost.com/eds/ebookviewer/ebook/bmxlYmtfXzE2NTAzOV9fQU41?sid=fb365bf5-d797-44ef-934a-c2b2b0a2d788@sessionmgr4004&vid=2&format=EB&rid=2.

[81] Joel Tickner & David Kriebel, The Role of Science and Precaution in Environmental and Public Health Policy, published in IMPLEMENTING THE PRECAUTIONARY PRINCIPLE : PERSPECTIVES AND PROSPECTS 42 (2006), *available at* http://eds.a.ebscohost.com/eds/ebookviewer/ebook/bmxlYmtfXzE2NTAzOV9fQU41?sid=fb365bf5-d797-44ef-934a-c2b2b0a2d788@sessionmgr4004&vid=2&format=EB&rid=2.

[82] Alan Patterson & Tim Gray, Unprincipled? The British Government's Pragmatic Approach to the Precautionary Principle, ENVIRONMENTAL POLITICS, 21.3 (2012) 432-450, 432. Sociological Collection. Web. 9 Sept. 2014, *available at* http://eds.a.ebscohost.com/eds/pdfviewer/pdfviewer?sid=fb365bf5-d797-44ef-934a-c2b2b0a2d788%40sessionmgr4004&vid=5&hid=4105.

"demonstrate the safety of environmentally hazardous activities."[83] Since its inception,[84] the principle has become one of the foundational bases guiding health and environmental policy decisions in multiple countries as well as the European Union.[85] Despite this early and successful formulation, the seminal articulation of the precautionary principle came from the 1992 United Nations Rio Declaration on Environment and Development. It provides that: "Where there are threats of serious and irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."[86] Although this version of the precautionary principle has been widely cited, it does not paint a complete picture of the principle's complexity. Its application across multiple states and international unions has led to multiple interpretations of the precautionary principle and disagreements over its application in environmental policies.[87]

Another variation of the precautionary principle comes from the Wingspread Declaration, which derives from a 1998 meeting of

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[83] Ragnar E. Löfstedt, Baruch Fischhoff & Ilya R. Fischhoff, Precautionary Principles: General Definitions and Specific Applications to Genetically Modified Organisms, JOURNAL OF POLICY ANALYSIS AND MANAGEMENT, 21, 3, pp. 381-407, (2002) ERIC, EBSCOhost, viewed 13 September 2014, *available at* http://onlinelibrary.wiley.com/doi/10.1002/pam.10051/pdf.

[84] Soon thereafter, the precautionary principle started appearing in German environmental policies, most notably in its 1974 Clean Air Act. *Id*. at 382-83.

[85] Patterson & Gray, *supra* note 82 at 433. ("Britain is bound by numerous European Union (EU) directives and regulations which inscribe the PP in its environmental and health policy-making, and as far back as 1990, the government acknowledged precaution as one of five principles to guide its policies on the environment . . . ."). Other international unions and non-European countries have followed suit, implementing the precautionary principle or some version of it into their policy-making framework. Mossman & Marchant, *supra* note 77 at 138.

[86] *Id*. at 138 (quoting United Nations Conference on Environment and Development, *Rio Declaration on Environment and Development* (United Nations 1992).

[87] *Id*. 138-39.

environmentalists. This version provides that precautionary measures should be taken when an activity threatens human health or the environment, "even if some cause-and-effect relationships are not established scientifically."[88] It places the burden of proof on the proponent of the activity, rather than the public.[89] Although this iteration of the principle is similar to the 1992 Rio Declaration version, the differences between them have proved a divisive subject in environmental policy discussion.

The variations of the precautionary principle fall generally into one of two categories, "strong" and "weak."[90] These versions of the precautionary principle differ primarily in the manner they address decision-making in the face of risk. The strong precautionary principle does not allow any room for additional considerations regarding the risk of serious harm. It rejects any activity or technology unless scientific evidence proves it does not harm the environment.[91] The strong precautionary principle places the responsibility of proving an activity safe or reasonable on the party advocating it, making precaution – prohibiting an activity – the default action.[92] It does not consider the degree of risk involved or the cost of making an activity safe, as under the weak precautionary principle. Instead, it asks whether a party can prove beyond reasonable scientific doubt that an activity is in fact safe

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88 Cass R. Sunstein, Beyond the Precautionary Principle, 151 U. PA. L. REV. 1003, 1005 (2003) (quoting Lessons from Wingspread, in IMPLEMENTING THE PRECAUTIONARY PRINCIPLE, *supra* note 80, app. A, at 353-54 (quoting the Wingspread Statement on the Precautionary Principle)).

89 *Id*.

90 Patterson & Gray, *supra* note 82 at 437.

91 *Id*.

92 Sunstein, *supra* note 88 at 1012-13.

for the environment.[93] Conservationists and environmental organizations favor this approach because it places the burden on potential actors to prove their activities are not harmful to the environment.[94]

Conversely, critics of the strong precautionary principle argue that it is too vague and offers no pragmatic guidance on how to accomplish its directives.[95] In addition, the exercise of excessive precaution may, in certain cases, inadvertently cause more harm than good. For example, consider the case of a substance that is toxic at higher levels but beneficial in smaller quantities. The strong precautionary principle, evidenced through a complete ban on the substance, may cause greater harm by preventing its beneficial applications.[96]

The "weak" version, on the other hand, is less stringent in determining how much precaution one should take.[97] Under the "weak" version of the precautionary principle, decisions regarding whether to continue or halt an activity are not made solely on whether a potential risk exists. The "weak" version also considers other factors, such as cost effectiveness. The 1991 Rio Declaration provides an example of this model.[98]

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[93] Noah M. Sachs, *Rescuing the Precautionary Principle from its Critics*, 2011 U. ILL. L. REV. 1285, 1295 (2011).
[94] Patterson & Gray, *supra* note 82 at 437 ("Here the onus is placed on the polluters to prove *beyond all doubt* that his/her polluting activities will not damage the environment: that is, there has to be *certainty* that no harm will befall the environment if no intervention is made.").
[95] Sunstein, *supra* note 88 at 1020.
[96] *Id*. at 1026-27.
[97] Sachs, *supra* note 93 at 1295.
[98] *See* Sunstein, *supra* note 88 at 1012; *see also* Sachs, *supra* note 93 at 1292-93. ("'Weak' versions of the Precautionary Principle stand for the proposition that regulators should be empowered to address risk in contexts of scientific uncertainty--that is, even before regulators fully understand the nature or extent

The effect of this type of approach to the precautionary principle is that it no longer functions as a guiding principle. The weak precautionary principle functions more as a balancing system that "allows evidence of negative socio-economic costs to be weighed against the positive environmental benefits of banning a harmful development."[99] The principle becomes a risk-management approach regarding potential risks of harm. Instead of erring on the side of caution and discontinuing an activity, the decision-maker considers the degree of the threat with the potential benefits of the activity and the possible results from its postponement.[100] Critics of the weak precautionary principle argue this balancing approach undermines the entire purpose of the precautionary principle altogether, which is to place the prevention of serious or irreparable harm above all else.[101]

B. We Should Consider Alternatives to Proposed Actions.

Before deciding whether to implement a new technology, decision makers often establish a framework identifying the available alternatives and developing for each a quantifiable measurement, explanation, and description.[102] Most people believe that actors can be blamed or praised for their actions only if they have the ability to choose to act differently; philosophers call this the principle of alternate

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of risk. One widely cited 'weak' version of the Precautionary Principle is contained in the Rio Declaration, adopted by consensus by 172 countries (including the United States) at the Earth Summit in 1992.").

[99] Patterson & Gray, *supra* note 82 at 437.

[100] *Id*. at 437.

[101] *Id*.

[102] 1 Fed. Envir. Reg. Of Real Estate § 1:8.

possibilities.[103] The principle of alternate possibilities states that before undertaking a certain action, a decision maker must consider alternative courses. This principle gives policymakers the flexibility to choose effectively among the various options.[104] When multiple possible outcomes for a given action exist, policymakers must balance the options and select the most beneficial one.

The National Environmental Policy Act (NEPA) provides a model of this approach. The explicit purpose of NEPA is to "ensure that environmental information is available to public officials and citizens before decisions are made and before actions are taken."[105] Through its requirement of an environmental impact statement (EIS), NEPA ensures that decision makers consider alternatives to their proposed action.[106] Emphasizing alternatives is central to the decision-making process,[107] and NEPA requires the presentation of alternatives to be in comparative form.[108] The comparison should sharply define the issues and provide a clear basis for choosing among the options.[109] The consideration of alternatives should include all reasonable courses of action and, for comparison, the no-action alternative.[110]

When considering the adequacy of alternatives under NEPA,

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[103] Luis E. Chisea, *Punishing Without Free Will*, 2011 UTAH L. REV. 1403, 1422-23 (2011).
[104] *Id*. at 1403.
[105] 40 C.F.R.§1500.1(b).
[106] 40 C.F.R. §1508.25(b).
[107] 40 C.F.R. §1502.14. Indeed, the consideration of alternatives is considered to be the "heart" of the NEPA process. *Id*.
[108] James Allen, NEPA Alternatives Analysis: The Evolving Exclusion of Remote and Speculative Alternatives, 25 J. LAND RESOURCES & ENVTL. L. 287, 294 (2005).
[109] *Id*. at 294.
[110] 40 C.F.R. §1502.14.

courts apply a standard of reasonableness.[111] Reasonableness is met when the EIS presents various alternatives, including the purpose and need for each alternative.[112] The EIS must "rigorously explore and objectively evaluate all reasonable alternatives," and, if the agency eliminates any alternative from detailed study, the agency must briefly discuss in the EIS why that alternative was not considered with the others.[113] The reasonableness of an alternative is usually defined in the negative; courts believe an agency may eliminate an alternative from consideration because it is unreasonable.[114] Alternatives which adequately address the proposal's need and purpose can also be considered unreasonable.

As NEPA demonstrates, the consideration of alternatives provides several benefits. First, it assures that the decision makers have considered methods of achieving the desired goal other than the proposed action.[115] Second, it assures that decision makers do not act on incomplete information or overlook or understate important effects.[116] Third, it better guarantees that the decision makers seriously consider the environmental effects of reasonable and realistic courses of action.[117]

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[111] *Associated Fiisheries of Maine,Inc. v. Daley*, 127 F.3d 104, 114 (1st Cir. 1997).
[112] 40 C.F.R. § 1502.14 (a).
[113] 38 Am. Jur. Proof of Facts 3d 547 (Originally published in 1996).
[114] Allen, *supra* note 108 at 295.
[115] Association Concerned About Tomorrow, Inc. v. Slater, 40 F.Supp.2d 823, 832 (N.D. Tex. 1998).
[116] American Canoe Ass'n v. White, 277 F.Supp.2d 1244, 1250 (N.D. Ala. 2003). The identification of alternatives documents that the decision makers have considered other approaches. Sierra Club v. Morton, 510 F.2d 813, 825 (5th Cir. 1975).
[117] Department of Transp. v. Blue, 147 N.C.App. 596, 604 (2001).

Finally, it fosters informed public engagement.[118]

C. We Should Avoid Creating a Moral Hazard.

A moral hazard is a concept from economics. It refers to the phenomenon that occurs when persons with insurance take greater risks than they would without insurance since they are insulated from the costs of their behavior.[119] A moral hazard arises when a party increases its risk taking when another party accepts some of the potential negative consequences of the first party's actions.[120] This concept most clearly arises in the context of insurance.[121] One commentator has even referred to it as "taking advantage" of insurance.[122] Researchers have found examples of this behavior in an array of insurance contexts, including health insurance, workers' compensation, automobile insurance, and even flood insurance.[123] They have also identified non-insurance contexts, ranging from the perpetration of genocide to the bail out of financial institutions, as involving similar concerns.[124]

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[118] Resources Ltd., Inc. v. Robertson, 35 F.3d 1300, 1306 (9th Cir. 1993). By providing informing regarding alternatives, the decision makers provide members of the public with information that they can evaluate and balance on their own. 510 F.2d at 825.

[119] Stephen M. Gardiner, Some Early Ethics of Geoengineering the Climate: A Commentary on the Values of the Royal Society Report, ENVIRONMENTAL VALUES 20 (2011): 163-188, 166.

[120] Jesse Reynolds, A Critical Examination of the Climate Engineering Moral Hazard and Risk Compensation Concern, THE ANTHROPOCENE REVIEW 3 (2014).

[121] Gardiner, *supra* note 119 at 166.

[122] Ben Hale, ENGINEERING THE CLIMATE (ed. Christopher J. Preston) 116 (2012).

[123] Albert C. Lin, Does Geoengineering Present a Moral Hazard?, 40 ECOLOGY LAW QUARTERLY 673, 686-87 (2013).

[124] *Id*. at 687-88. Other examples include mutual defense treaties, foreign aid, humanitarian intervention, and financial investments. Reynolds, *supra* note 120 at 4.

Nevertheless, the fit of moral hazard to climate engineering may be less than perfect. A moral hazard contemplates the existence of two parties with diverging interests.[125] Specifically, one party consensually transfers risk to the other party.[126] Geoengineering, on the other hand, involves multiple parties (global society) spread over time (multiple generations).[127]

Consequently, a concept related to moral hazard that may apply better to this context is risk compensation. This theory predicts that measures designed to reduce risk actually prompt more risky behaviors.[128] Essentially, reductions in exposure to risk encourage riskier conduct.[129] Examples of this shift in behavior occur when people use seatbelts, protective sports equipment, condoms, and hypertension drugs.[130] Several factors can influence risk compensation behavior. They include the visibility of the safety measure, the extent to which measures alter the perception of risk, the motivations underlying individual behavior, and the ability to control risk.[131]

D. We Should Minimize Harm to Future Generations.

The concept of intergenerational equity recognizes the entitlement of each generation to a planet comparable to that available to the previous generation.[132] It seeks to ensure a minimum planetary

[125] Lin, *supra* note 123 at 688.
[126] Reynolds, *supra* note 120 at 5.
[127] *Id*.
[128] Lin, *supra* note 123 at 689.
[129] *Id*.
[130] Reynolds, *supra* note 120 at 4.
[131] Lin, *supra* note 123 at 690.
[132] Edith Brown Weiss, Our Rights and Obligations to Future Generations for the Environment, 84 AM. J. INT'L L. 198, 200 (1990).

resource base for each generation as enjoyed by its ancestors.[133] From an alternative perspective, it preserves the largest possible range of options for future generations, thereby protecting their freedom of choice.[134] Intergenerational justice also addresses the sharing of harms and benefits across generations.[135] It is similar in concept to notions of trusteeship, stewardship, and tenancy, which require the conservation of assets so they are available for future groups.[136] "Future generations" as used in this principle is usually understood broadly, so as to include unborn persons into the future without limitation.[137] Furthermore, intergenerational equity recognizes an obligation to future generations regardless of the specific preferences or even the identities of these future individuals.[138]

Environmental proscriptions have incorporated intergenerational concerns since the 1970's. The 1972 Stockholm Declaration Preamble, for instance, identifies a goal of defending and improving the environment for "present and future generations."[139] Additional contemporaneous expressions of concern for future generations were included in the 1972 London Ocean Dumping Convention, the 1972

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[133] *Id*. at 200.
[134] Holly Doremus, The Rhetoric and Reality of Nature Protection: Toward a New Discourse, 57 WASH. & LEE L. REV. 11, 71-72 (2000).
[135] Toby Svoboda, et al, Sulfate Aerosol Geoengineering: The Question of Justice, p. 19, PUBLIC AFFAIRS QUARTERLY (2011). Svoboda notes an interrelationship between intergenerational and distributive justice. Specifically, present persons should not compromise the distributive justice of future generations. *Id*. at 20.
[136] *Id*.
[137] Burns H. Weston, Climate Change and Intergenerational Justice: Foundational Reflections, 9 VT. J. ENVTL. L. 375, 383-84 (2008).
[138] Bradford C. Mank, Protecting the Environment for Future Generations: A Proposal for a "Republican" Superagency, 5 N.Y.U. ENVTL. L.J. 444, 448-49 (1996).
[139] Preamble, Stockholm Declaration of the United Nations Conference on the Human Environment , U.N. Doc. A/ CONF. 48/14 (1972).

World Cultural and Natural Heritage Convention, the 1973 Endangered Species Convention, and the 1974 Charter of Economic Rights and Duties of States.[140] The 1987 report of the U.N. World Commission on Environment and Development (WCED) defined this interest more specifically. The WCED proclaimed that socioeconomic development that is to be sustainable must meet "the needs of the present without compromising the ability of future generations to meet their own needs."[141]

Domestic environmental laws similarly began to incorporate intergenerational concerns. For instance, the 1970 National Environmental Policy Act calls upon the Federal Government to use all practicable means so that the Nation may "fulfill the responsibilities of each generation as trustee of the environment for succeeding generations."[142] Similarly, the Wild and Scenic Rivers Act protects certain selected rivers "for the benefit and enjoyment of present and future generations."[143]

E. We Should Avoid Disparate Regional Impacts.

A related concern involves avoiding regional inequities. An unequal distribution might violate notions of distributive justice. Distributive justice concerns the sharing of harms and benefits among persons.[144] In the present context, the concern might arise not because of

[140] Weston, *supra* note 137 at 389.
[141] *Id*. at 390.
[142] 42 U.S.C.A. § 4331(b)(1).
[143] 16 U.S.C.A. § 1271.
[144] Svoboda, et al, *supra* note 135 at 9.

the distribution of harms among different individuals, but from harms imposed upon different regions of the world.[145]

While a number of egalitarian theorists have addressed distributive justice and the sharing of harms and benefits, perhaps the theories most on point are those of John Rawls. Rawls believes that two principles of justice should control. First, each person has an equal right to basic liberties; second, inequalities are to be to everyone's advantage and attached to positions open to all.[146] Thus, he would allow an unequal distribution of harms and benefits if this inequality benefits everyone, so long as it does not compromise persons' basic liberties and opportunities.[147] Although this theory could be understood to allow the unequal distribution of climate engineering harms, any compromise of groups' basic liberties and opportunities might violate this proscription.

Another conceptualization of distributive justice comes from Amertya Sen. Sen views the most important benefits as the basic capabilities that allow one to pursue the activities that one values; the most significant harms are the absence of such capabilities.[148] Among a person's basic capabilities are the ability to meet one's nutritional,

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[145] Similar but different principles would reach comparable results. The first concerns protection of vulnerable populations, especially those with reduced abilities to protect themselves. Pablo Suarez, Jason Blackstock & Maarten van Aalst, Towards a People-Centered Framework for Geoengineering Governance: A Humanitarian Perspective, GEOENGINEERING Q. (Oxford Geoengineering Inst., Univ. of Oxford), Mar. 2010, at 3, available at http://www.greenpeace.to/publications/The_Geoengineering_Quarterly-First_Edition-20_March_2010.pdf. Another dichotomy that commentators have identified arises between wealthy and poor nations. *Id*. These distinctions, while meaningful, are less clear, and in this context any disparate consequences stem less from those underlying differences than from the geographic location of the populations involved.
[146] Svoboda, *supra* note 135 at 10.
[147] *Id*. at 11.
[148] *Id*. at 12.

clothing, and shelter requirements.[149] Thus, actions that impair groups' ability to secure these necessities give rise to unjust distributions of them.

F. We Should Seek to Preserve the Natural State of the Environment.

Humans recognize an inherent value and dignity to the natural environment.[150] We appreciate the state of nature untouched by man's influence. Even more, we value the natural evolution of the environment and of species, absence manipulation by man to achieve a particular result dictated by humans.

Natural resources law and policy largely derives from concerns of preservation and restoration of ecological systems to earlier states.[151] This principle underlies the 1964 Wilderness Act. The Act identifies wilderness as an area "untrammeled by man" that "retain[s] its primeval character and influence, without permanent improvements."[152] It also recognizes an intrinsic value to the preservation of the wild character of certain lands.[153] Furthermore, maintaining the natural environment free of technological interference enables us to better understand the coexistence of species both among one another and with the

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[149] *Id*.
[150] Mark Sagoff, *We Have Met the Enemy and He Is Us or Conflict and Contradiction in Environmental Law*, 12 ENVTL. L. 283, 307-08 (1982).
[151] Alejandro E. Camacho, Transforming the Means and Ends of Natural Resources Management, 89 N.C. L. REV. 1405, 1426 (2011)
[152] Olivia Brumfield, *The Birth, Death, and Afterlife of the Wild lands Policy: The Evolution of the Bureau of land Management's Authority*, 44 ENVTL. L. 249, 255 (2014).
[153] Camacho, *supra* note 151 at 1427.

environment.[154] The natural state is important also because it best preserves biodiversity.[155]

This priority of the natural state has been recognized by at least one court. Nearly half a century ago, a property owner challenged a shoreline zoning ordinance that prohibited his filling of wetlands areas.[156] The Wisconsin Supreme Court held that the owner had "no absolute and unlimited right to change the essential natural character of his land so as to use it for a purpose for which it was unsuited in its natural state."[157]

Intergenerational equity[158] also supports preserving nature. Humans have an interest in conferring to subsequent generations a planet comparable to the one into which they were born. The natural environment also serves as a benchmark for future generations.[159]

A utilitarian perspective also supports preserving the natural state. Naturally functioning ecosystems provide a number of ecosystem services.[160] Ecosystem services include timber production, water supply, water purification, and maintenance of air quality.[161] Natural ecosystems generate and maintain biodiversity, too. Biodiversity provides genetic

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[154] Scott R. Sanders, A CONSERVATIONIST MANIFESTO 7 (2009).
[155] Christopher C. Joyner, Biodiversity in the Marine Environment: Resource Implications for the Law of the Sea, 28 VAND. J. TRANSNAT'L L. 635, 649 (1995).
[156] Just v. Marinette County, 56 Wis.2d 7, 14 (1972).
[157] *Id*. at 17.
[158] Discussed more fully *supra* at III.D.
[159] 56 Wis. 2d at 8.
[160] SUSTAINING LIFE: HOW HUMANS DEPEND ON BIODIVERSITY, foreword by Edward O. Wilson, edited by Eric Chivian and Aaron Bernstein 75 (2008).
[161] Rachelle Adam, *Missing the 2010 Biodiversit Target: A Wake Up Call For the Convention of Biodiversity?*, 21 COLO. J. INT'L ENVTL. L. POL'Y 123, 133 (2010).

resources critical to industries such as agriculture and medicine.[162] Without ecosystems, humans would be left to attempt to provide these services by themselves.[163]

Humans, of course, are not the only species that modifies the environment. The example often cited is that of beavers damming rivers.[164] Modifications initiated by humans, however, may be of a different nature and scale from those caused by other species. Humans can exert a disproportionate influence on a natural system, acting not as a part of nature but outside it.[165] In such circumstances, the changes imposed upon nature do not result from a series of species or system interactions, but, instead, result solely from the acts of a single species.[166] Furthermore, the acts of humans, unlike those of other species, can dramatically impact ecosystems and cause widespread destruction.[167]

Preservation of the natural state especially arises as a concern in the context of emerging technologies. The combination of a globalized economy and exponential advances in technological capacity enable the disruption of nature on a global scale.[168]

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[162] Matthew D. Bockey, To Keep Every Cog and Wheel: Preserving Biodiversity Through the Endangered Species Act's Protection of Ecosystems, 41 CAP. U. L. REV. 133, 156 (2013).
[163] *Id*. at 168.
[164] Marc Ereshefsky, Where the Wild Things Are: Environmental Preservation and Human Nature, BIOLOGY AND PHILOSOPHY, January 2007, Volume 22, Issue 1, pp 57-72, 62, available at http://people.ucalgary.ca/~ereshefs/publications/Wild%20Things.pdf.
[165] Bruce Pardy, Changing Nature: The Myth of the Inevitability of Ecosystem Management, 20 PACE ENVTL. L. REV. 675, 685 (2003).
[166] *Id*.
[167] Ereshefsky, *supra* note 164 at 62.
[168] Adam Corner, et al, Messing with Nature? Exploring Public Perceptions of Geoengineering in the UK, GLOBAL ENVIRONMENTAL CHANGE 23 (2013) 938-47, 940. Geoengineering even more squarely confronts these concerns, since it presents the prospect that humans will shape, manage, and control nature. *Id*.

G. We Should Avoid Irreversible Consequences.

Irreversibility of harm is a significant consideration in evaluating possible environmental damage and its prevention. "An effect is irreversible when restoration of the status quo is impossible or at best extremely difficult, at least on a relevant timescale."[169] While the concept seems simple, its application can be anything but. Actions may have irreversible consequences in one timeframe, but not in others. For instance, trees lost through deforestation can regrow.[170] Similarly, environmental destruction can be undone, but only at a high cost.[171] On the other hand, other actions unquestionably cannot be undone. Most species extinctions would fall into this category. Finally, irreversibility should also include an element of seriousness or magnitude.[172]

Irreversibility also can play a role in the application of the Precautionary Principle. Several applications of it require the utilization of precautionary actions upon threat of "irreversible damage."[173]

H. We Should Be Able to Contain the Effects of a Technology.

An important consideration is whether the consequences of a technology can be contained to their intended range. Since we may not always be able to foresee technology's consequences, we need to reduce

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[169] Cass Sunstein, Irreversible and Catastrophic, 91 CORNELL L. REV. 841, 860 (2006).
[170] *Id*.
[171] *Id*. at 862.
[172] *Id*. at 861. Thus, for example, the loss of an "extremely small forest, with little wildlife" would not suffice, even if it were irreversible. *Id*.
[173] *Id*. at 843-44.

the risk that they can escape to an unanticipated location. Both geographic and temporal containment are important.

Problems of containment have already arisen in the biotechnology field. New biotechnologies introduce organisms into certain environments, but these organisms often relocate to non-native environments through cross-pollination, wind and insects.[174] Once these organisms enter new environments, they tend to reproduce rapidly and invade the environment, thus becoming "invasive species."[175] These invasive species can alter the biodiversity of the environment through predation and hybridization.[176] In this context, hybridization occurs when genetically-engineered species cross breed with native species.[177] Thus, invasive species can diminish biodiversity in the environment by dominating the environment and eliminating native species.[178]

Protocols to address contamination come from NASA.[179] Prevention of contamination requires a thorough understanding of what constitutes contamination and the harmful effects to environments experiencing contamination.[180] Before implementing a contamination control procedure, policymakers need to determine the types of potential

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[174] Jonathan M. Jeschke, Felicia Keesing, & Richard S. Ostfeld, *Novel Organisms: Comparing Invasive Species, GMOs, and Emerging Pathogens*, AMBIO A JOURNAL OF THE HUMAN ENVIRONMENT, 2/7/13.
[175] *Id*. at 2.
[176] *Id*. at 4.
[177] Clint C. Muhlfeld, et al, Invasive Hybridization in a Threatened Species Is Accelerated by Climate Change, NATURE CLIMATE CHANGE 4, 620–624 (2014), published online 25 May 2014, http://www.nature.com/nclimate/journal/v4/n7/full/nclimate2252.html.
[178] Jeschke, Keesing, & Ostfeld, *supra* note 178 at 4.
[179] Sandia Corporation – a contract for NASA, CONTAMINATION CONTROL PRINCIPLES (1967), 1-53, 1. The agency has had to develop procedures to prevent contamination resulting from space travel. *Id*.
[180] *Id*. at 5.

contaminants and how they form and spread and the effects these contaminants may have on the environment.[181]

I. We Should Seek Solutions That Fully Resolve Problems.

A typical criticism leveled against SRM suggests another principle that should be considered. Commentators often charge that SRM technologies will not address the acidification of the oceans.[182] One might say this failure violates a principle of an incomplete or imperfect solution.[183] This article rejects this as a principle that should be applied when determining whether to deploy a geoengineering technology. Rarely does society develop complete solutions to our problems, and often it implements an array of partial solutions. One such example comes from medicine. No one has suggested that drugs that helped to address some of the symptoms of AIDS should be rejected on the grounds that no single drug provides a complete solution. Indeed, 30 years after the spread of this disease, the primary treatment for this illness involves a cocktail of drugs, each serving a unique purpose.[184] More should not be required of climate solutions.

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[181] *Id*. at 7.
[182] For example, *see* Robock, 20 Reasons, *supra* note 44 at 15. Some critics of SRM go so far as to assert that SRM actually causes ocean acidification. As Keith and MacMartin note, ocean acidification does not result from SRM. Instead, it results almost solely from CO_2 emissions. Keith & MacMartin, *supra* note 69 at 1.
[183] Carol Rose, Environmental Lessons, 27 LOY. L.A. L. REV. 1023, 1032 (1994) (noting that partial solutions run counter to much of our legal tradition).
[184] Julie Verville, Understanding the AIDS Cocktail, HEALTHLINE, February 19, 2013, http://www.healthline.com/health/hiv-aids/understanding-the-aids-cocktail#1.

IV. APPLICATION OF THESE PRINCIPLES CAN GUIDE DECISIONS TO DEPLOY CLIMATE ENGINEERING.

These legal principles can help guide decisions to deploy climate engineering technologies. Rather than make haphazard, *ad hoc* decisions, society can use these principles to develop a principled, reasoned, and replicable approach to determine whether to deploy a specific climate engineering technology. Furthermore, development of these principles before a climate emergency arises better ensures that an appropriate process is used to make decisions at such time and that society does not act reflexively in the face of an imminent climate catastrophe.

The remainder of this article will develop a structure to apply these principles to some of the most commonly-discussed geoengineering technologies. First it will review considerations that arise when applying these principles to geoengineering in general. Next, it will address issues that courts and social scientists have found when decision makers utilize multi-factor tests. Finally, it will apply these principles to actual climate engineering technologies. Application to these technologies demonstrates that these principles can help to clarify the relative advantages and disadvantages of different approaches.

A. Some General Conclusions Concerning All Geoengineering Methods.

Before applying the principles to specific technologies, some general conclusions applicable to all climate engineering methods should be considered. Some considerations, such as the goal of climate engineering, will guide the manner of deployment and its consequences.

Certain principles, such as the moral hazard and the precautionary principle, raise issues that apply to all technologies. Thus, reviewing these considerations will simplify the later process of applying the principles to particular technologies.

1. Determining the objective for intervening in the climate.

An accurate analysis of climate engineering technologies needs to begin with consideration of the objective for using them. Because of the termination effect,[185] a critical distinction turns on whether society were to deploy SRM to return the climate to its pre-warming level or instead to slow the rate of warming. In general, most of the studies of SRM assume that we would use these technologies to return the earth's climate to its pre-industrial condition.[186] Because this would require more extensive cooling,[187] the consequences of termination would be greatest under such deployment.[188]

Thus, certain deployments of SRM could raise concerns of intergenerational equity in two ways. First, if society used it in a manner that risked a termination effect, the current generation would be committing future generations to maintain the technology to avoid

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[185] Discussed *supra* at section II.C.

[186] For example, *see* Kelly E. McCusker, et al, Rapid and Extensive Warming Following Cessation of Solar Radiation Management, ENVIRON. RES. LETT. 9 (2014). McCusker, et al, conducted an "ensemble" of SRM simulations, including 20-year and 80-year implementation periods, applying different climate sensitivity values, and projecting both 5-year and 20-year trends after cessation. *Id*. at 2, 5-6. Despite this breadth of analysis, they simulated only abrupt SRM termination. *Id*. at 5.

[187] Douglas G. MacMartin, Ken Caldeira, & David W. Keith, Solar Geoengineering to Limit the Rate of Temperature Change, 372 PHIL. TRANS. R. SOC'Y A 1–13, 11 (2014).

[188] *Id*. at 2.

catastrophic consequences.[189] Second, investments in climate engineering would almost certainly divert funds otherwise available for other climate change responses, namely mitigation and adaptation.[190] In this way, it could create an intergenerational conflict, since the use of SRM could enable the current generation to force the greatest costs of mitigation and adaptation to be incurred by future generations.[191]

Alternatively, society might choose to deploy SRM only to slow the rate of warming or to partially offset the degree of warming.[192] The former would be beneficial, since, as noted previously, the rate of change is more harmful than the actual new global temperature.[193] Another objective might be to utilize SRM to buy time to implement additional mitigation and adaptation measures.[194] If society deploys SRM for these purposes, then less solar reduction will be required, and it will be needed over a shorter period of time.[195] Consequently, this will reduce the risks of using the SRM technology.[196] Furthermore, the termination effect

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[189] Holly Jean Buck, Climate Remediation to Address Social Development Challenges: Going Beyond Cost-Benefit and Risk Approaches to Assessing Solar Radiation Management, ENGINEERING THE CLIMATE: THE ETHICS OF SOLAR RADIATION MANAGEMENT 142 (2012). This intergenerational concern arises because the current generation "locks-in" a commitment to geoengineering, thereby reducing the choices for its descendants. *Id*. at 143-44.

[190] Reynolds, *supra* note 120 at 7.

[191] Patrick Taylor Smith, Domination and the Ethics of Solar Radiation Management, ENGINEERING THE CLIMATE: THE ETHICS OF SOLAR RADIATION MANAGEMENT 28 (2012). Conversely, a proponent of geoengineering might argue that SRM actually benefits future generations since it might better preserve species and ecosystems that would be destroyed by unchecked warming.

[192] Douglas G. MacMartin , Ken Caldeira, & David W. Keith, Solar Geoengineering to Limit the Rate of Temperature Change, 372 PHIL. TRANS. R. SOC'Y A 1, 2 (2014).

[193] *Id*.

[194] *Id*.

[195] *Id*.

[196] *Id*. at 11. As Keith and MacMartin note, the ratio of SRM's benefits to costs will be largest for very small amounts of SRM. Keith & MacMartin, *supra* note 69 at 5.

might be avoidable if SRM's use were phased-out rather than abruptly terminated.[197] Alternatively, we might choose not to maximize cooling, but instead to minimize the effects of warming. This reduced geoengineering again would generate fewer or weaker side effects.[198]

Thus, the intended objective for applying SRM can result in substantial differences in the possible consequences.

2. Certain principles apply equally – if at all – to all technologies.

The outcomes when applying two principles – the precautionary principle and the avoidance of a moral hazard – will likely be the same regardless of the technologies to which they are applied. First, we should exercise caution with all of these technologies. As discussed previously, lack of scientific certainty should trigger the precautionary principle.[199] We do not have scientific certainty concerning any of these methods at this time,[200] and perhaps whenever we might deploy climate engineering

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[197] MacMartin, Caldeira, & Keith, *supra* note 192 at 6. Discussions of the termination effect typically contemplate a binary choice between continued deployment and termination. *Id*. at 11. While we can hope that the entity governing particle injection would be responsible enough to avoid an abrupt cessation, a catastrophe such as a war or a pandemic might prevent the continuation of the injections. In such case, a "double catastrophe" of a rapid temperature increase would compound the effects of the initial catastrophe. Seth D. Baum, The Great Downside Dilemma for Risky Emerging Technologies, 89 PHYS. SCR. 4 (2014). If termination did not result from an initial catastrophe, the prospects are more encouraging. If SRM were terminated suddenly, a rapid re-initiation might reduce the termination effect. *Id*. at 6. A voluntary cessation, conversely, could involve a phase out at a rate that would reduce overall risk and damage. *Id*. at 11.

[198] G. Bala, Should We Choose Geoengineering to Reverse Global Warming?, CURRENT SCIENCE, Vol. 107, No. 12, 1939-40, 1940 (2014).

[199] *Supra* at III.A.3.

[200] For purposes of this discussion, this article does not consider non-technological, natural fixes, such as "bio-geoengineering" methods, which would increase the planting of plant species with specific leaf glossiness to maximize solar reflectivity. Andy Ridgwell, et al, Tackling Regional Climate

we will still lack scientific certainty.[201] Consequently, precaution should apply equally to all technologies. The weak precautionary principle, because of its breadth of factors and weighing process,[202] is more appropriate than its stronger sibling.

Critics raise the moral hazard as one of their primary objections to climate engineering:[203] They charge that it will remove the incentive to reduce fossil fuel use.[204] Essentially, if society can avert the worst consequences of climate change through geoengineering, then the primary incentive to undertake the societal and lifestyle changes required to mitigate will diminish. Thus, society will continue with business as usual (either maintaining levels of fossil fuel use or even increasing their use), relying upon climate engineering to avoid the worst effects of climate change.[205] Climate engineering will only treat the symptoms while ignoring the cause.[206] Even worse, it removes the incentive to address the cause of the problem.

Thus, resolution of the moral hazard, if it were to arise, appears to apply equally to all geoengineering technologies. Substantial research findings, however, question whether a moral hazard will actually develop. Researchers have found little indication that geoengineering will prompt problematic changes in behavior. They have conducted a

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Change By Leaf Albedo Bio-geoengineering, CURRENT BIOLOGY 19, 146–150, 150, January 27, 2009.

[201] *Id*. at 7 (identifying climate issues that would need to be understood).

[202] Patterson & Gray, *supra* note 82 at 437.

[203] The concept of moral hazard is discussed more fully *supra*, at III.C.

[204] Davis, *supra* note 34 at 946-47.

[205] Russell Powell, Steve Clarke, Mark Sheehan, Tom Douglas, Bennett Foddy, & Julian Savulescu, The Ethics of Geoengineering [Working Draft], (undated), at 2, available at http://www.practicalethics.ox.ac.uk/__data/assets/pdf_file/0013/21325/Ethics_of_Geoengineering_Working_Draft.pdf.

[206] *Id*.

number of studies to determine whether climate engineering might give rise to a moral hazard or risk compensation behavior. In general, these studies found that support for geoengineering tended to be conditioned upon a simultaneous pursuit of mitigation.[207] Indeed, despite any benefits of climate engineering, mitigation remains the preferred approach.[208] One study even found a possible reverse risk compensation effect – participants reported that they were more likely to support mitigation if the government pursued climate engineering.[209]

While this rationale may hold at the individual level, it may be less controlling at a broader level. Some commentators point out that geoengineering provides a policy option which will ease political pressure to mitigate.[210] Since climate engineering provides additional options to decision makers for responding to climate change, it can ease political pressure to mitigate.[211] In this way, it might give rise to a moral hazard while also creating an intergenerational concern: the current

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[207] Adam Corner & Nick Pidgeon, Geoengineering, Climate Change Scepticism and the 'Moral Hazard' Argument: An Experimental Study of UK Public Perceptions, 372 PHIL. TRANS. R. SOC'Y A 1, 5 (2014). Similarly, a GAO survey found that people are unlikely to consider geoengineering to be a substitute for mitigation. Lin, *supra* note 123 at 693. Corner and Pidgeon conducted one of the most recent studies concerning moral hazard and analyzed participants' responses by different personality types. *Id*. at 11. They concluded that discussion of a possible moral hazard "may . . . simply reinforce existing beliefs" supportive or opposed to climate engineering. *Id*. at 12. Moreover, they concluded that utilization of geoengineering is not likely to reduce mitigation efforts; instead climate engineering will coexist with mitigation, just as adaptation efforts now do. *Id*.

[208] Integrated Assessment of Geoengineering Proposals, PUBLIC AND OTHER STAKEHOLDER PERCEPTIONS OF GEOENGINEERING: FACILITATING RESPONSIBLE INNOVATION 2 (2014), available at http://www.iagp.ac.uk/.

[209] Reynolds, *supra* note 120 at 5-6.

[210] Lin, *supra* note 123 at 707.

[211] *Id*. at 707.

generations would effectively "kick the can" of addressing climate change to future generations.[212]

In conclusion, we might conclude that the evidence of a moral hazard is mixed. More pertinent here, however, nothing suggests that a moral hazard would be more likely to arise with one technology but not another. Thus, it would not provide a unique reason against deploying a particular technology, and it would serve questionable value as a separate principle.

3. Determining a baseline for comparison.

Another important issue to consider before applying the principles is the reference point for comparison. Should the results of climate engineering be compared to a business as usual scenario or to pre-industrial conditions? Obviously, this decision could yield vastly different results. The issue arises because many critics of climate engineering compare its results to a pre-industrial climate. With that baseline, they consider climate engineering to be "implementing highly untested and risky" technologies.[213] Others, however, argue that we are presently embarking upon another "highly untested and risky" experiment – the emission of greenhouse gases causing planetary

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[212] Reynolds, *supra* note 120 at 5. Conversely, one dollar spent on geoengineering will not necessarily take away a dollar for mitigation or adaptation. Geoengineering implementation costs are likely to be small compared to those of mitigation and adaptation. *Id*. at 7. Furthermore, climate engineering, by cooling the planet, reduces mitigation or adaptation costs. *Id*.

[213] Noah Deich, Are Negative Emissions a "Myth?", available at http://theenergycollective.com/noahdeich/2169321/are-negative-emissions-myth.

warming at unprecedented speed.[214] They maintain that we are already embarking upon a series of geoengineering experiments[215] that are at least as risky and uncertain as any proposed climate engineering would be.[216]

The business-as-usual scenario is the appropriate comparison. Emissions are still rising.[217] So is the global temperature.[218] Furthermore, they are likely to continue to do so at least for decades,[219] and the planet will stay at its "new normal" for centuries.[220] Accordingly, comparing the results of geoengineering to climate conditions that the Earth may not experience again for a millennia is pointless. Similarly, when the IPCC discussed geoengineering in its

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[214] Noah S. Diffenbaugh & Christopher B. Field, Changes in Ecologically Critical Terrestrial Climate Conditions, SCIENCE, Vol. 341, 486-492, 489-90 (August 2, 2013). When compared to other extreme changes in the climate (the Eocene-Oligocene glaciation and the Pleocene-Eocene Thermal Maximum) the current rate of warming is occurring at speeds 10 to 100 times faster. *Id*.

[215] Ridgwell, Freeman & Lampitt, *supra* note 55 at 4164 (climate engineering would represent the latest in a series of actions by humans, such as changing the albedo and hydrology of the land surface and, more recently, changing the greenhouse composition of the atmosphere and chemistry of the ocean, that affect the climate).

[216] Rose Cairns, Discussion paper: Will Solar Radiation Management Enhance Global Security in a Changing Climate? 26 (published online 12 November 2014). Or, as Jack Stilgoe put it, "Everything we know about geoengineering suggests it would be a bad idea. It's just a question of whether the alternative is even worse. If you think climate change is going to make the world a very bad place to live in, then geoengineering might be the better of the two evils." Joshi Herrmann , Stealing Your Thunder: Why Geoengineering Is One of Science's Most Contested Terrains, LONDON EVENING STANDARD, February 20, 2015, available at http://www.standard.co.uk/lifestyle/london-life/stealing-your-thunder-why-geoengineering-is-one-of-sciences-most-contested-terrains-10055867.html.

[217] WMO, *supra* note 2 at 1.

[218] NOAA, *supra* note 4.

[219] Matthews & Caldeira, *supra* note 11 at 1.

[220] Solomon, *supra* note 12 at 1704.

Fifth Assessment Report, benchmarked to the business-as-usual scenario.[221]

A related issue arises concerning the appropriate benchmark for determining violation of the natural state principle. Should the benchmark be the pre-warming state, a pre-industrial state, or a pre-humanity condition? For the same reasons as just discussed, the benchmark probably should be the post-warming environment. Nevertheless, the fact that these issues arise demonstrates that this principle might be unworkable.

B. Decision Making with the Principles.

An important consideration regarding the principles involves the process by which decision makers apply them. When applying checklists or extensive lists of factors, courts and researchers have recognized a number of approaches which can affect their utility. Often courts weigh the components of legal checklists or legal tests equally.[222] Such an approach, however, is not always appropriate or desirable. Consequently, decision makers, when confronted with applying multiple criteria, have adopted a number of different approaches. In some instances, courts eschewed merely totaling up the factors, favoring instead a "totality of the circumstances" approach.[223] This approach will better assure that the court considers all of the facts and circumstances

[221] WORKING GROUP I CONTRIBUTION TO THE IPCC FIFTH ASSESSMENT REPORT
CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS ("Working Group I") 7-64 (2013) (recognizing that SRM might reduce climate differences compared to a world with elevated greenhouse gas concentrations and no SRM).
[222] Zubulake v. UBS Warburg LLC, 217 F.R.D. 309, 322 (S.D.N.Y. 2003).
[223] Noble v. United States, 231 F.3d 352, 359 (7th Cir. 2000).

unique to every case, thereby best achieving fairness and equity.[224] Similarly, in other multi-factor determinations, decision makers applied a case-by-case determination, emphasizing flexibility in the application of a wide variety of factors.[225] In other cases, courts prioritized factors, recognizing that certain considerations carried greater importance than others.[226]

Decision makers, however, often do not apply multi-factor (or multi-principle) tests as they are intended. Social scientists have found that decision makers, when confronting complex decision processes, tend to limit the factors that they consider.[227] Empirical analysis in several contexts suggests that decision makers will seldom consider all relevant information when facing such decisions. Instead, at some point, they typically stop acquiring and analyzing information and commit to a decision.[228]

Thus, a risk exists that if the set of principles is too extensive, the decision makers will disregard some of them. Thus, some steps should be taken to assure that all of the principles are given their due. First, because of the tendency to ignore some factors in extensive lists, the set of principles should not be exhaustive.[229] Second, resolution of some principles may address issues raised by other principles. Finally, the

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[224] Adam Schlusselberg, Case Comment, In Re Davis, 53 N.Y.L. SCH. L. REV. 639, 649 (2008/2009).
[225] John S. Applegate, Worst Things First: Risk, Information, and Regulatory Structure in Toxic Substances Control, 9 YALE J. ON REG. 277, 302 (1992).
[226] 217 F.R.D. at 323.
[227] Barton Beebe, An Empirical Study of the Multifactor Tests for Trademark Infringement, 94 CAL. L. REV. 1581, 1601 (2006).
[228] *Id*..
[229] *Id*. at 1646.

principles should be prioritized.[230] This will also provide a clearer signal to decision makers of the relative importance of each principle.

Applying these concepts to the principles identified previously suggests several modifications for their application. Since an exhaustive list may be counterproductive, [231] the number of principles should be limited if possible. Fortunately, two of the principles – the precautionary principle and the moral hazard – have general application to all climate engineering technologies and do not need to be considered separately for each technology. Moreover, three principles overlap. Determining whether a remedy is effective is essentially subsumed in the cost-benefit analysis determination. Likewise, the weak precautionary principle and cost-benefit analysis both weigh benefits against risks. Finally, the principle of natural state is awkward to apply, since it is difficult to benchmark.[232]

Next, we must be prioritize the remaining principles. A critical determination is whether the technology will work and what its associated risks will be. Similarly, to avoid focusing exclusively on a particular technology, and to clarify the choices that are available (including maintaining the status quo), the consideration of alternatives is also a top priority. Thus, the resolution of these two principles – cost-benefit analysis and consideration of alternatives – should be a top priority, and deployment should not proceed without favorable

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[230] *Id*.
[231] *Id*. at 1601. Considering the scientific expertise required for these determinations, one possible approach to reduce the risk that some principles will not be fully considered would be to establish different panels of experts to address a particular principle.
[232] *Supra*, at section IV.B.

resolutions of them. Consistent with our societal concern in promoting equity and avoiding disparate impacts, the next priorities should be those principles targeted to avoiding such effects, intergenerational equity and regional equity. Finally, the decision makers should also consider reversibility and containability. While both of these concepts are important, the very nature of climate engineering may limit the ability of any technology to fully comply with these objectives. Nevertheless, any irreversible and extended consequences need to be taken into account.

One additional but important consideration is flexibility. Even courts applying extensive lists of factors realize that such lists are not necessarily complete.[233] Instead, these courts advocate flexibility in their application depending upon the circumstances of a particular decision.[234] Courts have especially recognized the possibility of considering new factors not previously identified in circumstances involving emerging technologies.[235] Similarly, although this article attempts to identify a complete set of legal principles that should bear on the deployment question, the author recognizes that unforeseen circumstances and technologies may arise necessitating additional considerations.

Finally, and perhaps most importantly, the conclusions drawn from the following application of these principles will change over time. These technologies are still in their infancy.[236] We can therefore rest

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[233] I.P. Lund Trading ApS v. Kohler Co., 163 F.3d 27, 43 (1st Cir.1998) (acknowledging that the eight-factors in a test to determine consumer confusion in trademark infringement cases are non-exclusive).
[234] 73 C.C.C.3d 348, 353 (Ont. Ct. Gen. Div. 1992).
[235] Douglas L. Rogers, Ending the Circuit Split over Use of A Competing Mark in Advertising-the Blackstone Code, 5 J. MARSHALL REV. INTELL. PROP. L. 157, 164-65 (2006)
[236] Working Group I, *supra* note 221 at 7-64.

assured that our knowledge of the application and effects of these technologies will evolve. Consequently, the conclusions drawn from the applications of these principles may change depending upon when they are applied. This will occur not just because of changes in the technologies but also because of changes in the global circumstances to which the results of climate engineering would be compared.[237] And, of course, all climate engineering technologies raise the possibility of unintended and unanticipated consequences.[238]

C. Application of These Principles Suggests That Some Geoengineering Solutions Might Be More Acceptable Than Others.

Although some general conclusions about climate engineering deployment are possible, unique characteristics of each technology necessitate application of the principles on a technology-by-technology basis. The following section applies the principles to a range of potential geoengineering methods. However, it directs particular attention to one technology: stratospheric aerosol injection.

Among the SRM techniques, the one method most extensively discussed has been atmospheric particle injection.[239] This method

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[237] Toby Svoboda, Is Aerosol Geoengineering Ethically Preferable to Other Climate Change Strategies, ETHICS & THE ENVIRONMENT, 17(2), 111-135, 120 (2012) (recognizing that at a future date a mitigation strategy could create more harm than an aerosol geoengineering strategy).

[238] Gary Cooper, et al, Preliminary Results for Salt Aerosol Production Intended for Marine Cloud Brightening, Using Effervescent Spray Atomization, 372 PHIL. TRANS. R. SOC'Y A 1, 2 (2014).

[239] Rasch, et al, *supra* note 31 at 4010 (noting that scientists have studied sulfate aerosols for many years because of their importance generally to the chemistry of the lower atmosphere and their specific effect following volcanic eruptions). Moreover, this method is one of the few methods for which a field test had been planned. Jack Stilgoe, Matthew Watson, & Kirsty Kuo, Public Engagement with Biotechnologies Offers Lessons for the Governance of Geoengineering

consists of injecting particles, usually sulfur, into the atmosphere to mimic the effects of volcanic eruptions.[240] Part of the technology's appeal arises because it derives from a natural process, volcanic eruptions, and the rapid cooling effects of numerous such eruptions are well documented.[241] Moreover, many scientists consider particle injection to be the "most promising" climate engineering system.[242] They consider it to be so for a number of reasons. Compared to other methods, particle injection would require less energy, be capable of relatively quick deployment, cost less, and could cool the planet rapidly.[243] Consequently, it is the most frequently discussed climate engineering system.[244]

A proper analysis of particle injection, however, first requires a determination of the purpose for which the system would be deployed.[245] As discussed previously, scientists studying SRM technologies have concluded that the manner of deployment will determine the technology's risks and benefits as much as any other consideration.[246] In

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Research and Beyond, PLOS BIOLOGY 2 (2013). Because of a controversy that arose regarding related patent rights, however, the organizers canceled the experiment. Daniel Cressey, Cancelled Project Spurs Debate over Geoengineering Patents, NATURE 429, 24 May 2012.

[240] Rasch, et al, *supra* note 31 at 4009.

[241] For instance, when Mount Pinatubo erupted in 1991, it cooled the globe by approximately 0.5° C in less than one year. David W. Keith, Edward Parson, & M. Granger Morgan, Research on global sun block needed now, NATURE 463:426-27, 426 (2010). After Mount Tambora's eruption in 1815, the subsequent cooling effect produced "the year without a summer." Stilgoe, *supra* note 239 at 1.

[242] Seth D. Baum, Timothy M. Maher, Jr., & Jacob Haqq-Misra, Double Catastrophe: Intermittent Stratospheric Geoengineering Induced by Societal Collapse, ENVIRON SYST DECIS (2013) 33:168–180, 168.

[243] *Id*. at 171-72.

[244] Adam D.K. Abelkop & Jonathan C. Carlson, Reining in Phaëthon's Chariot: Principles for the Governance of Geoengineering, 21 Transnat'l L. & Contemp. Probs. 763, 777-78 (2013).

[245] Keith & MacMartin, *supra* note 69 at 1.

[246] *Id*.

view of the significance of this distinction, this article will first apply the principles to particle injection, but it will do so first when it is used to return the plant's temperature to a pre-industrial level and then when the technology is used merely to reduce the rate of warming.

1. Particle injection to cool to pre-industrial levels.

If particle injection (or probably all other SRM technologies) were deployed to cool the planet to a pre-industrial level, it would fail most of the principles:

1. Alternatives /Outweighing benefits – these principles are combined because the answer to both principles would likely be circumstance dependent. Many scientists expect that particle injection would be used only to avert a climate catastrophe.[247] Thus, SRM deployment under such circumstances might be the best alternative and outweigh any anticipated risks, but mainly because the circumstances at the time of deployment might be so dire. Under less dire circumstances, particle injection might be less likely to be the best alternative or to outweigh its associated risks.[248]

2. Intergenerational equity – as indicated previously, the critical distinction between the two approaches concerns the consequences of using particle injection to restore a pre-industrial climate. An immediate shut off of the injection system would return the climate to its pre-cooled temperature, but the temperature would rise at

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[247] Barrett, *supra* note 24 at 47.
[248] See *supra*, Section II.C.

such a rapid rate that it might endanger many species and ecosystems.[249] Thus, this method would raise intergenerational concerns, since it commits future generations to maintenance of the injection system to avoid a cataclysmic rise in temperature.[250] Not only would future generations be committed to continue the system, research indicates that over time their commitment would need to increase, because the albedo reflectivity of the system would decline over time.[251]

3. Regional/geographic equity – scientists project that particle injection would create significant regional disparities.[252] Essentially, regional differences inhere with particle injection. Scientists expect the technology to cause weather patterns to change adversely in many parts of the globe.[253] Over time, its use would cause different regions to experience different climate modifications, including regional

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[249] Kelly E McCusker, et al, Rapid and Extensive Warming Following Cessation of Solar Radiation Management, ENVIRON. RES. LETT. 9, 1-2 (2014)
[250] Marion Hourdequin, Geoengineering, Solidarity, and Moral Risk, in ENGINEERING THE CLIMATE 28 (edited by Christopher J. Preston) (2012).
[251] P Heckendorn, et al, The Impact of Geoengineering Aerosols on Stratospheric Temperature and Ozone, ENVIRON. RES. LETT. 4, 11 (2009). This results from a key difference between volcanic eruptions and sulfuric particle injection – the former is a singular event, while the latter will involve continuous repetition. Baum, *supra* note 242 at 173. Consequently, over time the newly-injected particles coagulate with previously injected particles, growing to a size that the combined particles gravitationally settle faster, shortening their atmospheric residence times. In addition, larger particles are less efficient in scattering shortwave radiation. As a result, to maintain the same cooling effect, the amount of sulfur injected into the atmosphere would need to increase over time. *Id*. Thus, while commentators commonly analogize this technology to a natural process (Adam Corner & Nick Pidgeon, Like artificial trees? The Effect of Framing by Natural
Analogy on Public Perceptions of Geoengineering, CLIMATIC CHANGE 5, published online May 17, 2014), available at
http://link.springer.com/article/10.1007%2Fs10584-014-1148-6), significant distinctions arise in the manner of particle injection.
[252] Svoboda, Aerosol Geoengineering, *supra* note 237 at 115-16.
[253] Burns, *supra* note 28 at 40.

differences in precipitation.[254] Anticipated effects include a decrease in average annual precipitation in Africa, South America, and southeastern Asia.[255] Furthermore, the effects on temperature and precipitation would not only vary significantly, they would also follow different trajectories.[256]

4. Reversibility – even if particle injection were "shut off" abruptly, the injected particles would remain in the atmosphere for up to five to ten years.[257] Thus, if the injection of particles was adversely impacting the environment – for instance, altering precipitation patterns more severely than anticipated – such consequences might not be reversible in the short term. Although global-scale effects on temperature and rainfall would eventually recover to pre-injection levels, significant lasting changes in regional patterns would remain.[258] Of course, the consequences of the termination effect – destruction of a significant portion of ecosystems and species[259] – could not be reversed.

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[254] Nancy Tuana, The Ethical Dimensions of Geoengineering: Solar Radiation Management through Sulphate Particle Injection, Working Paper 2 (2013), available at http://geoengineeringourclimate.com/2013/06/11/the-ethical-dimensions-of-geoengineering-solar-radiation-management-through-sulphate-particle-injection-working-paper/#_ftn6.
[255] *Id*. at 3.
[256] Katharine L. Ricke, M. Granger Morgan & Myles R. Allen, Regional Climate Response to Solar-Radiation Management, NATURE GEOSCIENCE, 537-41, 537 (August 2010).
[257] Baum, *supra* note 197 at 4. *But see* MacMartin, Caldeira, & Keith, *supra* note 192 at 11 (identifying the residence time of aerosols as lasting between one and two years).
[258] Integrated Assessment of Geoengineering Proposals, PRACTICALITIES OF GEOENGINEERING: COULD THE DEVIL BE IN THE DETAIL? 3 (2014), available at http://iagp.ac.uk/.
[259] Burns, *supra* note 28 at 48.

5. Containability – this system would not satisfy containment, since its effects would be global.[260] Specifically, the technology operates by injecting sulfur particles into the atmosphere, where scientists would expect them to mix and disperse so as to affect "a larger area."[261] Similarly, sulfur eruptions from volcanoes mix in the atmosphere and diffuse solar radiation globally.[262]

Application of the principles to a pre-industrial cooling scenario suggests that this approach might be unduly risky. The principles indicate that this approach will have equity concerns, both intergenerational and regional. Also, its effects will not be containable. Although its effects might be reversible, at best this will occur only after several years. The principles suggest that this approach might be an acceptable response to a climate catastrophe, but even that conclusion relies upon the assumption that no other alternatives will be available to avert the catastrophe.

2. Particle injection to constrain warming.

On the other hand, many of these concerns would not arise if we were to deploy particle injection to achieve different objectives, i.e., slowing the rate of warming or avoiding extreme warming. Specifically, an application of the principles would reach the following conclusions:

[260] Indeed, one scientist, Alan Robock, has suggested that any SRM method will significantly modify the global climate system because of non-local climate responses. John Latham, et al, Marine Cloud Brightening ("Marine Cloud Brightening"), 370 PHIL. TRANS. R. SOC. A 4217–4262, 4248 (2012).
[261] Rasch, et al, *supra* note 31 at 4008.
[262] *Id*. at 4032.

1. Alternatives /Outweighing benefits – again, the triggering climate emergency would likely involve a rapid warming or a regional crisis.[263] Although these triggering events might differ, they still would be catastrophic in nature. Furthermore, few (most likely no) other alternatives presently exist that could provide as rapid a cooling effect. Consequently, as above, particle injection would again likely satisfy these principles, though this conclusion would be circumstance dependent. Furthermore, utilizing particle injection below its maximum level will be optimal, because the negative consequences of the system will multiply faster than do its benefits as the amount of solar geoengineering increases.[264]

2. Intergenerational equity – under this scenario, particle injection would be deployed only temporarily.[265] Consequently, such deployment would likely avoid the risk of the termination effect. First, it would be deployed with an endpoint in mind.[266] Thus, barring an accident or unexpected catastrophe, the deployers would likely have a plan to ratchet down the system.[267] Second, the need to maintain the system for a millennium is not inherent with particle injection, but instead results from the manner in which it is deployed. Accordingly,

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[263] Barrett, *supra* note 24 at 47.
[264] Keith & MacMartin, *supra* note 69 at 5; *see also* MacMartin, Caldeira, & Keith, *supra* note 192 at 11 (reducing the amount of particle injection reduces the risks associated with the technology).
[265] Keith & MacMartin, *supra* note 69 at 2.
[266] MacMartin, et al, note that using SRM to constrain the rate of temperature change will inherently limit the period of deployment – models indicate that temperature increases eventually stabilize, thus obviating the need to continue SRM. MacMartin, Caldeira, & Keith, *supra* note 192 at 3.
[267] Keith & MacMartin, *supra* note 69 at 8 (discussing a method to slow the rate of warming which would have an implied commitment to a measured wind down).

such deployment could avoid triggering the termination effect.[268] Thus, the intergenerational concern would be significantly reduced.

3. Regional/geographic equity – a limited deployment would produce fewer disparities in geographic weather. Reduced precipitation, for instance, results entirely from the magnitude of SRM applied.[269] Thus, applying less particle injection would minimize the risks of regional inequities.

4. Reversibility – some of the consequences of particle injection would remain the same: if circumstances necessitated (or caused) an immediate cessation, then these particles and their effects would linger up to several years.[270] Conversely, since this approach would likely involve a gradual racheting up and down of the injection of particles,[271] a greater likelihood exists that its consequences will more quickly reverse. Plus, it contemplates a shorter deployment duration,[272] which should increase the speed with which its consequences could be reversed.

5. Containability – as noted previously, sulfur particles will mix in the atmosphere and initiate global reactions.[273] Thus, the inherent characteristics of this technology will prevent its consequences from being limited in geographic scope.

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[268] Keith & MacMartin, *supra* note 69 at 2.
[269] *Id*.
[270] *See* n.257 and accompanying text.
[271] Keith & MacMartin, *supra* note 69 at 9 (favoring a gradual and moderate implementation of SRM even if it were to be used to avert a climate emergency).
[272] MacMartin, Caldeira, & Keith, *supra* note 192 at 11.
[273] *Supra*, n.260 and accompanying text.

Application of the principles to slow the rate of warming suggests that this approach would have reduced risk. While a potential for intergenerational and regional equity concerns could arise, they are less likely to arise when less particle injection is used. Similarly, the system would be easier to reverse if problems arose. While concerns remain, the principles suggest that this method would be worth more serious consideration.

3. Cloud brightening and cloud thinning.

Other SRM technologies also should be considered using the principles. Unfortunately, other methods have not been considered for as long or as thoroughly as has particle injection. Nevertheless, this section will review some of the other prominent SRM technologies and discuss how the principles might apply to them.

Marine cloud brightening is a relatively new concept.[274] The technology would use fleets of ships to spray sea water into the air below marine clouds, thereby increasing the clouds' reflectivity and longevity.[275] Scientists project that this method could approximately counter-balance the warming caused by up to a doubling of atmospheric carbon dioxide.[276] They also expect this method to be reasonably safe.[277]

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[274] Scientists first proposed marine cloud brightening around 2000. Piers Forster, Not Enough Time for Geoengineering to Work?, BULLETIN OF THE ATOMIC SCIENTIST (Feb. 2, 2015), available at http://thebulletin.org/not-enough-time-geoengineering-work7963.

[275] P. J. Connolly, et al, Factors Determining the Most Efficient Spray Distribution for Marine Cloud Brightening, 372 PHIL. TRANS. R. SOC'Y A 1, 2 (2014).

[276] John Latham, et al, Marine Cloud Brightening: Regional Applications ("Regional Applications"), 372 PHIL. TRANS. R. SOC'Y A 1, 2 (2014).

[277] Philip W. Boyd, Ranking Geo-engineering Schemes, NATURE GEOSCIENCE, November 2008, 722-24, 724 (concluding that cloud whitening

Supporting this conclusion are two aspects of this technology. First, it could be shut off almost immediately, "with essentially all of the sea water droplets returning to the ocean within a few days."[278] Second, this technology may enable scientists to limit its deployment to produce only a localized effect,[279] thereby reducing the likelihood of regional inequities. Nevertheless, as discussed more fully below, some disparities would result since the cooling effect would occur only over the oceans.[280]

As discussed below, cloud brightening might pass muster with several of the principles:

1. Outweighing benefits – inherent to cloud brightening, its effects are anticipated to be nonlinear and, thus, scalable. So, for instance, 25% of its potential cooling effect could be achieved with only 5-15% of the potential cloud seeding.[281] This aspect of the technology might minimize negative consequences.[282] Also, in contrast to chemicals used in other aerosol proposals, seawater is both non-polluting and non-toxic,[283] further reducing the likelihood of adverse consequences. Nevertheless, scientists have identified potential risks. For instance,

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would be ranked second among five geoengineering methods on three measurements of safety).

[278] Latham, Marine Cloud Brightening, *supra* note 260 at 4256. The global response to the system would, however, continue for "a much longer time." John Latham, et al, Global Temperature Stabilization via Controlled Albedo Enhancement of Low-Level Maritime Clouds ("Global Temperature Stabilization"), 366 PHIL. TRANS. R. SOC'Y A 3969-3987, 3969 (2008). This contrasts significantly with particle injection, whose particles would not fall from the atmosphere for at least one year five to ten years. *Supra* n.257 and accompanying text.

[279] Latham, Regional Applications, *supra* note 276 at 3 Indeed, this is one of the major benefits of this technology, since it may be applied to mitigate or avert regional consequences, such as Arctic sea ice melting, *id*., or sub-sea permafrost thawing. *Id*. at 5.

[280] Latham, Global Temperature Stabilization, *supra* note 278 at 3982.

[281] Latham, Regional Applications, *supra* note 276 at 9.

[282] *Id*.

[283] Cooper, *supra* note 238 at 2.

although it would likely reduce precipitation globally, it might actually increase runoff over land.[284] Moreover, cloud brightening's effects are expected to worsen, not reduce, both the warming and the drying experienced in parts of the globe, especially South America.[285] It would likely also cause regional changes in sea surface temperatures, which might alter ocean circulation patterns and modify regional weather systems.[286] Accordingly, the technology would still create risks, though, on balance, they might not outweigh its benefits. For these reasons, the benefits of cloud brightening would likely outweigh its risks.

2. Alternatives – similar to particle injection, cloud brightening might only be used in the event of a climate catastrophe, particularly a melting of the ice caps.[287] Thus, the application of this principle will likely depend either upon the circumstances or the other available options. However, as discussed above, cloud brightening's reliance upon non-polluting substances and its inherent regional character may provide it with an advantage over other SRM technologies. Still, the consideration of alternatives would be important.

3. Intergenerational equity – because of the limited lifetime of its effects,[288] cloud brightening raises few intergenerational concerns.

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[284] G. Bala, et al, Albedo Enhancement of Marine Clouds to Counteract Global Warming: Impacts on the Hydrological Cycle, CLIMATE DYNAMICS, Vol. 37, Issue 5-6, 915-931, 929 (2011).

[285] *Id*.

[286] David L. Mitchell, Subhashree Mishra1 & R. Paul Lawson, Cirrus Clouds and Climate Engineering: New Findings on Ice Nucleation and Theoretical Basis 258 (in PLANET EARTH 2011 - GLOBAL WARMING CHALLENGES AND OPPORTUNITIES FOR POLICY AND PRACTICE, edited by Elias Carayannis) (2011).

[287] Latham, Regional Applications, *supra* note 276 at 5-6.

[288] Latham, Marine Cloud Brightening, *supra* note 260 at 4256.

4. Regional/geographic equity – as mentioned above, cloud brightening by its nature alters only oceanic clouds.[289] As a result, the technology's effects on land precipitation and distribution of cooling tend to differ from those induced by greenhouse gases.[290] As discussed above, in South America, it would actually enhance the warming and drying caused by greenhouse gases.[291]

5. Reversibility – as discussed before, cloud brightening's effects would be both short lived and relatively localized.[292] Thus, its direct consequences would be quickly reversible.

6. Containability – for largely the same reasons, cloud brightening's effects would be more containable than would the effects of some other technologies, such as particle injection. Although the technology would alter only marine clouds, these changes would still have some effects over land.

Application of the principles suggests that marine cloud brightening could be a promising technology. Nevertheless, despite these possible advantages, scientists acknowledge significant uncertainties concerning cloud brightening remain,[293] as do possible unintended consequences.[294]

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[289] Latham, Regional Applications, *supra* note 276 at 3.
[290] Andy Jones, Jim Haywood, & Olivier Boucher, A Comparison of the Climate Impacts of Geoengineering by Stratospheric SO_2 Injection and by Brightening of Marine Stratocumulus Cloud, ATMOS. SCI. LET. 12:176-183, 180 (2010).
[291] *Id*. at 180-81.
[292] Latham, Marine Cloud Brightening, *supra* note 260 at 4248, 4257.
[293] Antti-Ilari Partanen, Direct and Indirect Effects of Sea Spray Geoengineering and the Role of Injected Particle Size, JOURNAL OF GEOPHYSICAL RESEARCH, Vol. 117, Issue D2,
[294] Cooper, *supra* note 238 at 2.

An even newer potential SRM technology[295] is cirrus cloud thinning.[296] This technology would apply a different approach to solar radiation: rather than reflect incoming sunlight, as do sulfur particle injection and marine cloud brightening, this method would reduce cirrus clouds to facilitate the release of outgoing radiation.[297] Cirrus clouds act similarly to greenhouse gases by trapping outgoing longwave radiation.[298] This climate engineering method would seed cirrus clouds with ice nuclei that reduce cloud coverage and cloud lifetimes.[299] Consequently, more longwave radiation would be able to escape the atmosphere.

Because of cloud thinning's recency as a concept, a full analysis under the principles would be especially premature. However, consideration of some aspects of the technology would still be informative. Cloud brightening's effects could be stopped within weeks;[300] limiting its intergenerational impacts. Furthermore, two

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[295] Actually, some scientists consider this to constitute a third climate engineering branch, which they categorize as earth radiation management, or ERM, since it would adjust the troposphere to reduce surface temperatures. Mitchell, Mishra1 & Lawson, *supra* note 286 at 258 (in Planet Earth 2011 - Global Warming Challenges and Opportunities for Policy and Practice, edited by Elias Carayannis) (2011).

[296] This technology was first proposed in 2009. T. Storelvmo, et al, Cirrus Cloud Seeding Has Potential to Cool Climate, GEOPHYSICAL RESEARCH LETTERS, VOL. 40, 178–182, 178 (2013).

[297] John Latham, Philip J. Rasch & Brian Launder, Climate Engineering: Exploring Nuances and Consequences of Deliberately Altering the Earth's Energy Budget, 372 PHIL. TRANS. R. SOC'Y A 1, 3 (2014).

[298] Mitchell, Mishra1 & Lawson, *supra* note 286 at 259. In fact, the effect of cirrus clouds is so significant that scientists consider their life cycle and cloud coverage to be the second most important process affecting climate sensitivity. *Id*. The clouds also produce a cooling effect by reflecting sunlight, but overall they have a net warming impact. *Id*.

[299] *Id*. at 259-60.

[300] *Id*. at 262.

possible seeding materials, bismuth trilodide and sea salt, are nontoxic,[301] thereby minimizing some of the possible risks of the technology. On the other hand, it may cause regional inequities by altering regional and seasonal weather patterns.[302]

This discussion demonstrates the value of the principles. They provide a set of established considerations with which to analyze proposed technological remedies to climate change damage. Particularly important is the ability to distinguish among technologies objectively. Because of the gravity of the circumstances under which such decisions might be made, predetermining the bases for making such determinations is critical.

V. CONCLUSION

Humanity's extraordinary impact on the climate will require that we consider extraordinary responses. We may soon have technologies that can minimize the consequences of climate change. However, we need a set of principles that can help us determine the appropriate courses to take. The proffered principles derive from established legal doctrines. They enable us to develop a set of reasoned and replicable standards to apply to these technologies. Use of these principles can assist decision-makers and society as a whole when contemplating the deployment of geoengineering.

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[301] H. Muri, et al, The Climatic Effects of Modifying Cirrus Clouds in a Climate Engineering Framework, J. GEOPHYSICAL RES.: ATMOSPHERES, Vol. 119, 4174-91, 4174 (2014).
[302] *Id*. at 4189.