# GEO-MARKETS

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## INTRODUCTION

Global responses to climate change so far have failed to set out a legal roadmap which would make it possible to overcome global warming. Scholars and the popular press hailed the Paris Agreement in particular as the "new hope" for world society to address climate change when it was adopted in late 2015.[2] But almost from the moment of the Paris Agreement's adoption, commentators conceded that the participating states' commitments will fall significantly short of the agreement's stated goal of keeping the Earth's temperature within 1.5°C to 2°C of pre-industrial levels.[3] Records of compliance with the terms of the agreement are not entirely disheartening,[4] but they certainly do not suggest overachievement.[5] The world currently comes up short in its efforts at self-restraint with regard to greenhouse gas ("GHG") emissions.

If we look underneath these top sheet performance figures measuring compliance with the Paris Agreement contributions, the current state of affairs sadly gets worse rather than better. The most recent climate summit, known informally as COP25,[6] ended in "failure."[7] The summit was supposed to increase ambition in climate mitigation strategies and to establish rules for the carbon emissions market outlined in Article 6 of

2 *See* Daniel Bodansky, *The Paris Climate Change Agreement: A New Hope?*, 110 AM. J. INT'L L. 288 (2016).

3 Umair Irfan, *Climate Pledges Will Fall Short of Needed 2 Degree C Limit*, SCI. AM. (Nov. 3, 2016), https://www.scientificamerican.com/article/climate-pledges-will-fall-short-of-needed-2-degree-c-limit/?redirect=1.

4 IPCC, SPECIAL REPORT, GLOBAL WARMING OF 1.5° C 51 (2018).

5 *Id.*

6 COP25 refers to the twenty-fifth annual meeting of the Conference of the Parties, the "supreme decision-making body of the" United Nations Framework Convention on Climate Change (UNFCCC). *See* Conference of the Parties, United Nations Climate Change, https://unfccc.int/process/bodies/supreme-bodies/conference-of-the-parties-cop (last visited Feb. 10, 2020).

7 David Keating, *Failure In Madrid As COP25 Climate Summit Ends In Disarray*, FORBES (Dec. 15, 2019), https://www.forbes.com/sites/davekeating/2019/12/15/failure-in-madrid-as-cop25-climate-summit-ends-in-disarray/#38c7d8ac3d1f.

the Paris Agreement, permitting states to enter into a global cap-and-trade regime.[8] In the end, however, the summit failed to accomplish either goal because of acrimonious fighting over how emission reductions in a carbon trading market would be counted toward achieving Paris Agreement climate mitigation goals.[9] Mitigation, it turns out, is hard to achieve, even in the face of strident activism embodied most forcefully by one of its youngest standard bearers, Greta Thunberg.[10]

The problem does not end there. Even during the negotiations over the Paris Agreement, states balked at the kind of mitigation efforts activists demanded. The decarbonization commitments made by many states to reduce net GHG emissions under the Paris Agreement include carbon removal from the atmosphere as a means to comply with their respective targets. Such commitments assume the existence of technology that has yet to be developed on a commercial scale: the ability to "suck" carbon dioxide and other GHGs out of the atmosphere and somehow make these gases harmless or inert.[11] This technology is known as "carbon capture," "carbon removal" or "carbon capture and store."[12] Needless to say, the Paris Agreement does not create any legal infrastructure to support the development or deployment of this critical technology—in fact, it says nothing at all on the subject.[13]

The failure of COP25 and the inclusion of carbon removal in the original Paris Agreement commitments both point to a blind spot in the current climate regime. Deep decarbonization measures cannot succeed without a strong market mechanism. But this market mechanism cannot get off the ground because states are not able to agree on a cap on new

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8 *Id.*; Paris Agreement to the United Nations Framework Convention on Climate Change art. 6, Dec. 13, 2015, in Rep. of the Conference of the Parties on the Twenty-First Session, U.N. Doc. FCCC/CP/2015/10/Add.1, annex (2016) [hereinafter Paris Agreement]; *What are Market and Non-Market Mechanisms?*, UNFCCC.int, https://unfccc.int/topics/market-and-non-market-mechanisms/the-big-picture/what-are-market-and-non-market-mechanisms (discussing the cap and trade aspects of Article 6 mechanisms).

9 For a discussion of the failure of COP25, *see* Diane Desierto, *COP25 Negotiations Fail: Can Climate Change Litigation, Adjudication, and/or Arbitration Compel States to Act Faster to Implement Climate Obligations?*, EJILTALK! (Dec. 19, 2019), https://www.ejiltalk.org/cop25-negotiations-fail-can-climate-change-litigation-adjudication-and-or-arbitration-compel-states-to-act-faster-to-implement-climate-obligations/.

10 *Id.*

11 Eli Kintisch, *Technologies*, *in* CLIMATE ENGINEERING AND THE LAW, REGULATION AND LIABILITY FOR SOLAR RADIATION MANAGEMENT AND CARBON REMOVAL 28-56 (Michael B. Gerard & Tracy Hester eds. 2018); BENOIT MAYER, THE INTERNATIONAL LAW ON CLIMATE CHANGE 158 (2018).

12 Kintisch, *supra* note 6, at 41-51.

13 Jesse Reynolds, *International Law*, *in* CLIMATE ENGINEERING AND THE LAW, REGULATION AND LIABILITY FOR SOLAR RADIATION MANAGEMENT AND CARBON REMOVAL 57, 69-70 (Michael B. Gerard & Tracy Hester eds. 2018).

emissions that is low enough to make emissions trading a meaningful way to meet Paris Agreement goals—instead, states wish to count old reductions already baked into current climate projections to meet new mitigation goals.[14] Such a duplicitous emissions accounting system shows that carbon mitigation is not politically feasible even in Australia—a country currently feeling the effects of massive wildfires thought to be caused by climate change.[15] Structurally, the only way to break the current deadlock is to bring a carbon removal market to life so as to sidestep the mitigation deadlock. But the Paris Agreement does not have answers as to how to support carbon removal technology and to how to create a carbon market.

This blind spot in the current legal regime to fight climate change is mission critical. Scientists have issued dire warnings that climate change likely may reach a "tipping point" by 2030.[16] If GHG emissions have not been brought under control by that time, climate change may well become irreversible.[17] Worse still, if climate change reaches a "tipping point," a system of positive feedback loops will exponentially worsen the climate trajectory by, for example, freeing GHGs previously trapped in permafrost, changing the heat absorption rate of the earth, and even altering the rotation of the planet due to the effect of melting ice on the weight distribution of water around the globe.[18] This chain reaction, if it comes to pass, may make large parts of the planet uninhabitable—or at the very least, may make certain areas unable to support the populations currently living there.[19] Nonetheless, while climate scientists tell us that there is no time to spare, the key agreement intended to combat climate change takes a wait-and-see attitude.

To resolve this urgent problem, we must design a legal mechanism to develop carbon capture and storage technology on a commercial scale that is capable of closing the gap between current GHG mitigation efforts

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14 Desierto, *supra* note 9.

15 Charis Chang et al., *Australia is Among a Number of Countries Being Blamed for Blocking Climate Agreement at COP25*, NEWS.COM.AU (Dec. 17, 2019), https://www.news.com.au/technology/environment/climate-change/australia-is-among-a-number-of-countries-being-blamed-for-blocking-climate-agreement-at-cop25/news-story/730cb3aa0db89c0ce495482e3cbf02fa; Matt Simon, *Australia Is Blazing Into the Pyrocene—the Age of Fire*, WIRED (Jan. 3, 2020), https://www.wired.com/story/australia-is-blazing-into-the-pyrocene-the-age-of-fire/.

16 *See* IPCC, *supra* note 4, at 12.

17 Jane Dalton, *Climate Change Experts Urge May to Challenge Trump over Environmental Policies*, INDEPENDENT (June 3, 2019), https://www.independent.co.uk/environment/trump-visit-climate-change-global-warming-may-environment-letter-a8941041.html.

18 Stephanie Ebbs, *Scientists: Time Running Short Before Climate Change Effects Are 'Irreversible'*, ABC (Oct. 8, 2018), https://abcnews.go.com/International/united-nations-report-details-looming-climate-crisis/story?id=58354235.

19 DAVID WALLACE-WELLS, THE UNINHABITABLE EARTH: LIFE AFTER WARMING (2019).

and the GHG climate tipping point that scientists predict is near at hand.[20] This mechanism also must buy us time to complete the parallel processes of emission mitigation and carbon removal from the atmosphere should proof of concept arrive too late in the day to be fully deployed ahead of the climate tipping point. Together, the technology underlying such a mechanism is typically described as "geoengineering."

Current scholarship on geoengineering focuses on the regulation of technology.[21] To the extent this scholarship considers markets for implementation, it regards carbon taxation as a panacea.[22] But as the Yellow Vest protests in France have shown, this carbon tax approach risks provoking populist backlash.[23] This Article takes a first step toward designing geo-markets capable of raising the capital needed to achieve the necessary GHG emission reductions independent of carbon taxation approaches.

The geo-markets that this article advocates are markets to support a technological effort on the scale of the "moon shot." This technological effort would seek to support two types of technologies that, when operating together, have the ability to overcome the climate change challenge humanity faces today. These technologies are known as "geoengineering" or "climate engineering," and they address climate change from two directions—removing GHGs from the atmosphere and reducing solar radiation coming to the Earth's surface, thereby limiting the energy input trapped in the atmosphere by GHGs.[24]

To set up these geo-markets, this Article suggests that we need to look beyond treating climate change as only an environmental law problem—it is a commons management and energy law problem as well. Thus, what stands in the way of successful climate change mitigation efforts is that both economic activity and development depend upon energy, and

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[20] *See* Ebbs, supra note 18.

[21] *See* Tracy Hester, *Liability and Compensation*, *in* CLIMATE ENGINEERING AND THE LAW, REGULATION AND LIABILITY FOR SOLAR RADIATION MANAGEMENT AND CARBON REMOVAL 224-267 (Michael B. Gerard & Tracy Hester eds., 2018); Michael Burger & Justin Gundlach, *Research Governance*, *in* CLIMATE ENGINEERING AND THE LAW, REGULATION AND LIABILITY FOR SOLAR RADIATION MANAGEMENT AND CARBON REMOVAL 269-322 (Michael B. Gerard & Tracy Hester eds., 2018).

[22] Michael B. Gerrard & Tracy Hester, *Conclusions and Recommendations*, *in* CLIMATE ENGINEERING AND THE LAW, REGULATION AND LIABILITY FOR SOLAR RADIATION MANAGEMENT AND CARBON REMOVAL 324, 325-26 (Michael B. Gerard & Tracy Hester eds. 2018).

[23] Peter S. Goodman, *Inequality Fuels Rage of 'Yellow Vests' in Equality-Obsessed France*, N.Y. TIMES (Apr. 15, 2019), https://www.nytimes.com/2019/04/15/business/yellow-vests-movement-inequality.html.

[24] MAYER, *supra* note 11, at 145-60.

existing energy infrastructure in its cheapest form is GHG intensive.[25] Any attempt to reduce GHG emissions therefore has an immediate and tangible impact on economic activity.[26] Moreover, the Yellow Vest protests against the French government's imposition of carbon taxes on fuel demonstrated an additional unintended consequence of a pure environmental law solution: when applied to a carbon tax, the classic environmental law principle that polluters should pay for the clean-up of their pollution disproportionately affects poorer members of society and disproportionately deprives less-developed states of the ability fully to industrialize.[27]

This Article suggests that it is possible to solve both the environmental and energy problems presented by climate change by looking to an energy-inspired solution: a market that offers meaningful pricing incentives to develop and deploy technology to remove GHGs from the atmosphere. Borrowing from the concessional structures in the energy field, this market could offer freely transferable licenses to "produce" GHGs from the atmosphere. The issuer of the concession would then guarantee to pay a price for each ton of greenhouse produced from the atmosphere, so long as the license holder meets its work obligations to remove at least a certain amount of GHGs from the atmosphere after a certain maximum period of time. To receive this right to produce GHGs, the license holder initially pays (rather than receives payment from) the issuing governmental entity, thus making available capital with which the state can finance additional mitigation efforts by market means.

This Article will argue that such an approach is consistent with the nature of climate change as a "stock" and "flow" problem rather than merely a "flow" problem.[28] Climate change is not occurring because of the year-to-year emissions of GHGs ("flow"), but because the absolute levels of GHGs in the atmosphere are too high ("stock"). Even if the flow of emissions ended now, this would do nothing to reduce the stock of GHGs already in the atmosphere.[29] In fact, if the world stopped emitting GHGs tomorrow, this would exacerbate climate change because particles emitted by coal-fired power plants into the atmosphere over the Southern Hemisphere act as a solar radiation shield—a shield that would disappear

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[25] Nick Cunningham, *Energy Costs: Renewables Close in on Fossil Fuels, Challenging on Price*, USA TODAY (Apr. 4, 2018), https://www.usatoday.com/story/money/energy/2018/04/04/energy-costs-renewables-close-fossil-fuels-challenging-price/485210002/.

[26] CASS R. SUNSTEIN, LAWS OF FEAR, BEYOND THE PRECAUTIONARY PRINCIPLE 172 (2005).

[27] Goodman, *supra* note 17.

[28] MAYER, *supra* note 11, at 1-6.

[29] *See id.*

overnight if all emissions stopped at once.[30] This Article submits that any legal infrastructure intended to move the needle on climate change in a meaningful way must address a market for both stock reduction and for flow mitigation.

Centrally, this effort to create a legal infrastructure would set up two parallel geo-markets. The first market would be designed for the development and deployment of carbon removal technology. It would extend the market where feasible to existing license holders of coal-fired and other GHG-intensive power plants to replace existing power plants with forms of alternative energy free of GHG emissions. This market would support such a buyout if the construction of replacement generation capacity costs less than carbon removal from those power plants.

The other piece of the puzzle is to create a second regulated marketplace for worst-case scenario prevention. It will provide a market for solar radiation management,[31] a technology that brings with it a host of ethical and market problems—namely because it only alleviates a symptom of climate change rather than addressing a cause of the phenomenon.

Nevertheless, with the timing of climate scientists' predictions, such technology may need to be deployed to delay reaching the global climate change tipping point until other technologies can remove enough GHGs from the atmosphere permanently and thereby forestall reaching that tipping point.[32] The key insight from the literature on solar radiation management technology is that it must be regulated before it is deployed. This Article submits that the most cogent way to do so is to set up a market in which the use or non-use of solar radiation management technology could be traded and to integrate that market into the other two geo-markets to avoid abuse.

This Article has four parts. Part I outlines the problems faced by the current climate regime, particularly when it comes to the need for geoengineering markets without providing the infrastructure to create them. Part II then argues that part of the problem is that climate policy focuses predominantly on environmental law, though incorporating tenets of energy law can create a paradigm switch conducive to setting up geo-markets. Part III calls for the creation of the first geo-market for carbon removal and the means to integrate some payouts for existing GHG-intensive generation in this model. Part IV then addresses the

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[30] CLIVE HAMILTON, EARTHMASTERS, THE DAWN OF THE AGE OF CLIMATE ENGINEERING 70-71 (2013).

[31] MAYER, *supra* note 11, at 149-50.

[32] *See id.*

unique problems of creating a geo-market for solar radiation management and suggests pathways for overcoming these issues in the short term. Finally, the Article concludes that geo-markets are a useful design tool to overcome the collective action problems created by climate change to bring sidelined actors—the economy and world civil society—more actively into efforts to combat climate change.

## I. THE PARIS GAP

### *A. Racing Against the Clock*

Time is running out. Anthropogenic climate change—that is, the manmade alteration of the climate—is the result of global GHG emissions in the billions of tons per year.[33] The greater the concentration of GHGs in the atmosphere, the more these GHGs retain solar energy that would otherwise be radiated back into space.[34] This in turn causes climate change due to the effects of the increased, retained heat energy on the climate system.[35] Sufficient changes to the climate system will have materially adverse effects on ecosystems and human life.[36] The world is on an atmospheric countdown clock that runs down with each year of continued GHG emissions.

GHG emissions resemble a countdown clock because the world will undergo an explosive climate chain reaction once emissions are sufficiently elevated to trigger "feedback loops" built into the climate system.[37] For example, at a certain increase in global temperatures, the world will lose its polar ice sheets, and this will change a large part of the Earth's surface color from reflective white to energy-absorbing dark grey, further amplifying heat retention.[38] On land, melting permafrost will free large amounts of methane from ancient decomposing plant and animal life, adding a further powerful accelerant to climate change.[39] There are many similar events[40] that will likely trigger each other with each burst

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33 IPCC, *supra* note 4.

34 *The Basics of Climate Change*, THE ROYAL SOC., https://royalsociety.org/topics-policy/projects/climate-change-evidence-causes/basics-of-climate-change/ (last visited June 4, 2019).

35 *Id.*

36 *Id.*

37 Fiona Harvey, *'Tipping Points' Could Exacerbate Climate Crisis, Scientists Fear*, GUARDIAN (Oct. 9, 2018), https://www.theguardian.com/environment/2018/oct/09/tipping-points-could-exacerbate-climate-crisis-scientists-fear.

38 Brandon Keim, *7 Tipping Points that Could Transform Earth*, WIRED (Dec. 23, 2009), https://www.wired.com/2009/12/tipping-elements/.

39 Raj Saha, *The Permafrost Bomb Is Ticking*, YALE CLIMATE CONNECTIONS (Feb. 12, 2018), https://www.yaleclimateconnections.org/2018/02/the-permafrost-bomb-is-ticking/.

40 *See* Keim, *supra* note 38 (discussing different scenarios).

of global warming they respectively unleash.[41] Scientists speak of such events as potential "tipping points" or "tipping elements" at which the climate will change in an exponential progression and at a speed that outstrips nature's (and perhaps mankind's) ability to respond or adapt.[42]

It is now eleven minutes to midnight on our countdown clock. The leading body of climate scientists, the Intergovernmental Panel on Climate Change ("IPCC"), has estimated that, assuming current yearly emissions, some tipping points may be as little as eleven years away. For example, the IPCC estimates with regard to the first tipping event discussed above that "the probability of a sea ice-free Arctic Ocean during summer is substantially lower at global warming of 1.5°C when compared to 2°C."[43] The IPCC projects with "medium confidence" with regard to the second tipping event that holding global warming at 1.5°C would help to prevent the process of thawing permafrost.[44] Moreover, the IPCC has "high confidence" that the 1.5°C threshold could be crossed at current emission levels as early as 2030.[45] In short, by 2030, the world may be locked in to experiencing the exponential and irreversible impacts of climate change.

This entails a new reality: climate change no longer is a hypothetical problem for a future generation.[46] It is a problem *today* for *this* generation. To put this in perspective, the median age of the world's population is approximately 28 years.[47] That means that climate scientists are warning us that the effects of run-away climate change will begin when today's "median world human" is about 40 years old. To make matters worse, even with the greatest global resolve to fight climate change, stopping the phenomenon suffers from three major problems.[48]

First, climate change is a stock problem, not just a flow problem.[49] The problem is the total accumulation of GHGs in the atmosphere, or "stock," not just the amount of GHGs emitted yearly, or "flow."[50] The yearly flow

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41 *Id.*

42 *See id.* (discussing scientific interest in tipping points).

43 IPCC, supra note 4, at 10.

44 *Id.*

45 *Id.* at 6.

46 *See* STEPHEN M. GARDINER, A PERFECT MORAL STORM: THE ETHICAL TRAGEDY OF CLIMATE CHANGE (2011) (discussing the intergenerational ethical problems created by climate change).

47 *Median Age of World Population, 1950-2050*, PEW RESEARCH CENTER (Mar. 26, 2015), https://www.pewforum.org/2015/04/02/main-factors-driving-population-growth/pf_15-04-02_ch1graphics_medianage310px/.

48 HAL HARVEY ET AL., DESIGNING CLIMATE SOLUTIONS: A POLICY GUIDE FOR LOW-CARBON ENERGY 7 (2018).

49 *Id.*

50 *Id.*

of GHGs increases the total stock of GHGs, which stay in the atmosphere for up to 200 years.[51]

Second, even completely stopping the flow of GHGs into the atmosphere may not immediately mitigate climate change. Existing GHGs may continue to increase the Earth's temperatures because the temperature-increasing effect of GHGs potentially lags behind emissions.[52] That is, GHGs are just part of the climate change equation and interact with other parts of the climate system.[53] The process takes time to find a new equilibrium, meaning that warming may outlast an emissions stoppage.[54]

Third, stopping GHG emissions will in fact accelerate climate change in the short term. Current coal-fired power plants in operation, particularly those on the Indian subcontinent and elsewhere in Asia, are emitting pollution that has created a smog-dome over a significant portion of the Southern Hemisphere,[55] and this dome prevents solar energy from getting through.[56] If all coal-fired power plants were shut off tomorrow, this smog-dome would soon disappear.[57] The problem is that this will permit more energy to reach the Earth, and that heat energy will be trapped by the GHGs already in atmosphere. This will lead to a noticeable increase in temperatures *because of* reductions in pollution from fossil fuel burning.[58] Stopping all fossil fuel burning when the countdown hits "0:07," like it does in the movies, alone would not defuse the climate bomb.

### *B. The Paris Mitigation Approach*

World leaders understood that the 2015 Paris Agreement likely represented the last opportunity to beat the clock.[59] It was hailed as the last best hope of addressing the risks of climate change.[60] In fact, the earlier failures of the Copenhagen round of climate negotiations in 2009 led some to argue that time had already run out for a mitigation-based

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51 *Climate Change 2001: The Scientific Basis*, IPCC, https://archive.ipcc.ch/ipccreports/tar/wg1/016.htm.

52 Thomas Lukas Frölicher et al., *Continued Global Warming After $CO_2$ Emissions Stoppage*, 4 NAT. CLIM. 40, 40-44 (2014).

53 *Id.*

54 *Id.*

55 HAMILTON, *supra* note 30, at 70.

56 *Id.*

57 *Id.*

58 *Id.*

59 Edward-Isaac Dovere, *Obama Casts Climate Talks as World's Last Best Chance*, POLITICO (Nov. 30, 2015), https://www.politico.com/story/2015/11/obama-climate-change-paris-216251.

60 *Id.*

approach to climate change that relied on the reduction of GHG emissions.[61] Therefore, the Paris Agreement may already be outside the window in which climate change could effectively be combated through GHG reductions alone.[62]

The Paris Agreement cements the practice of avoiding a specific temperature increase associated with tipping elements as a goal of climate governance.[63] The movement towards this approach began at the Copenhagen round of climate negotiation in 2009.[64] While Copenhagen concluded in only a political agreement rather than a legally binding one,[65] the political goals enshrined in the agreement fundamentally changed the trajectory of climate law in two ways. First, it identified a specific temperature goal needed to safely avoid the climate tipping point: 2°C above pre-industrial levels.[66] The Paris Agreement adopted and improved upon this goal by seeking to halt global temperature increases to stay below the 1.5°C mark, a point at which significant climate feedback loops could be triggered, such as devastating sea level rise.[67]

The Paris Agreement also followed the Copenhagen agenda in another regard. Climate change obligations traditionally were subject to the principle of differentiation outlined in the 1992 United Nations Framework Convention on Climate Change ("UNFCCC") and its Kyoto Protocol.[68] This principle provides that only "developed countries" as defined under the UNFCCC have an obligation to mitigate GHG emissions, while "developing countries" (those not defined as developed countries) have no such obligation.[69] The rationale for this differentiation was and remains highly controversial. Industrializing countries insist that differentiation is appropriate because developed countries are at fault for

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61 *See* Louise Gray, *Copenhagen summit is last chance to save the planet, Lord Stern*, TELEGRAPH (Dec. 2, 2009), https://www.telegraph.co.uk/news/earth/copenhagen-climate-change-confe/6701307/Copenhagen-summit-is-last-chance-to-save-the-planet-Lord-Stern.html; John Vidal et al., *Low Targets, Goals Dropped: Copenhagen Ends in Failure*, THE GUARDIAN (Dec. 18, 2009), https://www.theguardian.com/environment/2009/dec/18/copenhagen-deal (discussing immediate reaction to the failure to reach a comprehensive climate deal in Copenhagen).

62 HAMILTON, *supra* note 49, at 16.

63 Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 13, 2015, in Rep. of the Conference of the Parties on the Twenty-First Session, U.N. Doc. FCCC/CP/2015/10/Add.1, annex (2016) [hereinafter Paris Agreement].

64 DANIEL BODANSKY ET AL., INTERNATIONAL CLIMATE CHANGE LAW 23-5 (2017); BENOIT MAYER, *supra* note 6, at 43-45.

65 BODANSKY, *supra* note 58, at 23-5; MAYER, *supra* note 6, at 43-45.

66 ALEXANDER ZAHAR, CLIMATE CHANGE FINANCE AND INTERNATIONAL LAW 7 (2018).

67 *Compare* Paris Agreement, *supra* note 57, at art. 2(a) (setting the warming goal) *with* IPCC, *supra* note 4, at 51 (outlining risk of sea level rise).

68 BODANSKY, *supra* note 58, at 26-30; MAYER, *supra* note 6, at 89-107.

69 *See* citations in note 62.

climate change in the first place.[70] Alternatively, developed states submit that differentiation is appropriate because developed countries are uniquely capable of meeting the challenge without threatening that economic development.[71]

In principle, world leaders agreed at Copenhagen that climate change mitigation was not just a developed world obligation.[72] It was a global obligation subject to a responsibility to make available financing to states to mitigate emissions and adapt to climate change.[73] The Paris Agreement again followed Copenhagen in focusing on global GHG mitigation that looked to available means when making mitigation commitments, but which did not describe those means as a condition precedent to mitigation.[74]

The Paris Agreement took a "bottom up" mitigation approach to avoiding the global warming threshold 1.5°C.[75] This approach requires all participating states to submit nationally determined contributions to achieving the global mitigation goal.[76] It is intended to help break the potential deadlock that a stricter approach would have faced in light of the significant disagreement related to the questions of differentiation which had been sidestepped by both the Copenhagen approach and Paris Agreement itself.

This approach is meaningfully different from earlier (failed) attempts at climate governance established in the Kyoto Protocol.[77] First, the national mitigation goals were not negotiated or imposed upon member states from the international "top down" as had been the case in the Kyoto Protocol model.[78] Instead, each member established its own contribution unilaterally without such negotiation.[79] Second, and just as important, the Paris Agreement itself does not mandate compliance with these unilateral

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70 BODANSKY, *supra* note 58, at 27.

71 *Id.*

72 ZAHAR, *supra* note 60, at 86.

73 *Id.*

74 Paris Agreement, *supra* note 57, at art. 4(3); for a discussion of differentiation in the Paris Agreement negotiations, *see also* BODANSKY, *supra* note 58, at 222, 224.

75 BODANSKY, *supra* note 58, at 214.

76 *Id.*; *see also* Frederic G. Sourgens, *Climate Commons Law: The Transformative Effect of the Paris Agreement*, 50 NYU J. INT'L L. & POL. 885 (2018).

77 ZAHAR, *supra* note 60, at 16.

78 *Id.*

79 Paris Agreement, *supra* note 57, at art. 4(2).

nationally determined contributions.[80] It merely mandates their communication with the rest of the world.[81]

The Paris Agreement hopes to create momentum towards a robust climate change policy through GHG emission cutbacks.[82] It provides for a periodic update of nationally determined contributions, and[83] it pushes states to set increasingly ambitious goals.[84] More importantly, embedded in the Paris Agreement is the hope that early compliance with its commitments will create political momentum quickly enough to increase the ambition of emissions cutbacks ahead of the communication deadlines for new nationally determined contributions.[85] Rather than mandating compliance, the Paris Agreement is intended to create a driving force towards voluntary efforts to mitigate climate change that can look to the example of the world community at large.[86]

### *C. The Current Paris Under-Performance*

The Paris Agreement model has come under significant strain. As it stands, the Paris Agreement has not created sufficient momentum towards meeting its goal of avoiding the tipping point of global warming of well below 2°C in the first round of nationally determined contributions.[87] Part of this blame falls on the policies of specific politicians like U.S. President Donald J. Trump who reversed policies expressly intended to meet U.S. Paris Agreement mitigation goals.[88] Other politicians with a similarly skeptical stance have since come to power in Australia and Brazil and have in turn implemented policies that undercut the Paris Agreement.[89]

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[80] Daniel Bodansky & Peter Spiro, *Executive Agreements+*, 49 VAND. J. TRANSNAT'L L. 885, 918 (2016); Harold Hongju Koh, *Triptych's End: A Better Framework to Evaluate 21st Century International Lawmaking*, 126 YALE L.J. F. 338, 350-62 (2017).

[81] Paris Agreement, *supra* note 57, at art. 4(2).

[82] Sourgens, *supra* note 70, at 904.

[83] Paris Agreement, *supra* note 57, at art. 4(9).

[84] *Id.* at art. 4(3).

[85] Sourgens, *supra* note 70, at 974-81.

[86] *Id.*

[87] IPCC, *supra* note 4, at 56 ("The current NDCs, extending only to 2030, do not limit warming to 1.5°C. Depending on mitigation decisions after 2030, they cumulatively track toward a warming of 3°-4°C above pre-industrial temperatures by 2100, with the potential for further warming thereafter.").

[88] *See generally* Carol J. Miller, *For A Lump of Coal & A Drop of Oil: An Environmentalist's Critique of the Trump Administration's First Year of Energy Policies*, 36 VA. ENVTL. L.J. 185 (2018) (discussing early Trump administration climate policies); Frederic G. Sourgens, *The Paris Paradigm*, 2019 U. ILL. L. REV. 1637 (2019).

[89] Damien Cave, *It Was Supposed to Be Australia's Climate Change Election, What Happened?*, N.Y. TIMES, (May 19, 2019), https://www.nytimes.com/2019/05/19/world/australia/election-climate-change.html;_Lisa Viscidi & Nate Graham, *Brazil Was a Global Leader on Climate*

But as the December 2019 COP25 summit in Madrid has shown, the current problem is too systemic to blame it solely on a few specific politicians.[90] President Trump's announced intention to exit from the Paris Agreement was greeted by claims that China would become the new global leader in the fight against climate change.[91] Even China—a country that did not undergo a leadership change since the conclusion of the Paris Agreement—has now turned away from decarbonization and back towards coal.[92] In fact, China was one of the countries roundly blamed for the failure at COP25.[93]

So, what happened? First, COP25 did nothing to reverse the string of record-setting increases in yearly carbon emissions.[94] It should have been a moment to increase both ambition and propose concrete strategies to mitigate climate change,[95] but the leading carbon emitters did not use COP25 to make any such meaningful commitments.[96] And worse, these countries thwarted efforts to agree on strong climate finance mechanisms.[97] Moreover, COP25 had an important structural brief. COP25 was supposed to reach agreements on three key Paris implementation milestones: rules on a carbon market, transparency requirements for reporting, and common timeframes within which states

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*Change. Now It's a Threat.*, FOREIGN POL'Y (Jan. 4, 2019), https://foreignpolicy.com/2019/01/04/brazil-was-a-global-leader-on-climate-change-now-its-a-threat/.

90 Keating, *supra* note 7.

91 *See* Anita Engels, *Understanding how China is Championing Climate Change Mitigation*, 4 PALGRAVE COMMUN. 1 (2018) (setting out the basis for claims of China's global climate leadership).

92 Daniel Oberhaus, *China Is Still Building an Insane Number of New Coal Plants*, WIRED (Nov. 27, 2019), https://www.wired.com/story/china-is-still-building-an-insane-number-of-new-coal-plants/; *Xi Jinping Fast Facts*, CNN (last updated Jan. 6, 2020), https://www.cnn.com/2013/01/04/world/asia/xi-jinping—-fast-facts/index.html.

93 Stuart Lau, *COP25 Summit: China Leads Four-Nation Attack over 'Imbalances' in UN Climate-Change Negotiations*, S. CHINA MORNING POST (Dec. 12, 2019), https://www.scmp.com/news/china/diplomacy/article/3041711/cop25-summit-china-leads-four-nation-attack-over-imbalances-un; Marlowe Hood, *Five Reasons COP25 Climate Talks Failed*, PHYS.ORG (Dec. 25, 2019), https://phys.org/news/2019-12-cop25-climate.html.

94 David Wallace-Wells, *U.N. Climate Talks Collapsed in Madrid. What's the Way Forward?*, N.Y. MAG. (Dec. 16, 2019), http://nymag.com/intelligencer/2019/12/cop25-ended-in-failure-whats-the-way-forward.html.

95 *Id.*

96 *See* Matt McGrath, *Climate Change: Major Emitters Accused of Blocking Progress at UN Talks*, BBC (Dec. 11, 2019), https://www.bbc.com/news/science-environment-50736617.

97 Umair Irfan, *The US, Japan, and Australia Let the Whole World Down at the UN Climate Talks*, VOX (Dec. 18, 2019), https://www.vox.com/energy-and-environment/2019/12/18/21024283/climate-change-cop25-us-brazil-australia-japan.

would make climate pledges. However, COP25 failed to reach agreement on all three.[98]

Setting rules for a carbon market under Article 6 of the Paris Agreement was particularly important as it would set rules allowing states struggling to meet their Paris commitments to "purchase" any commitment over-achievement made by another state,[99] and under which the private sector could decarbonize pursuant to the Paris framework.[100] The proposal on the table at COP25 would have included a robust accounting system for the carbon market to avoid double counting and strong reporting requirements for market participants.[101] These accounting rules covered both the sending side of the mitigation achievement to make sure that the mitigation outcome was truly additive to the country's own Paris commitment and the receiving side taking credit for the additional mitigation outcome through the market mechanism.[102] A potential agreement on a marketplace for trading carbon credits was also apparently within striking distance.[103]

Double counting is a key risk for such a mechanism.[104] This is precisely the issue that ultimately derailed adoption of the proposal. The key sticking point was the insistence by some states upon rules to allow double counting of carbon credits towards the Paris Agreement framework that accrued under the prior Kyoto Protocol carbon market.[105] In particular, China, India and Brazil wished to be able to carry over old credits from the Kyoto Protocol mechanism for past mitigation action to

[98] CARBON BRIEF, COP25: KEY OUTCOMES AGREED AT THE UN CLIMATE TALKS IN MADRID, https://www.carbonbrief.org/cop25-key-outcomes-agreed-at-the-un-climate-talks-in-madrid (last visited Feb. 10, 2020).

[99] Kelley Kizzier, *What You Need to Know About Article 6 of the Paris Agreement*, ENVT'L DEF. FUND CLIMATE 411 BLOG (Dec. 2, 2019), http://blogs.edf.org/climate411/2019/12/02/what-you-need-to-know-about-article-6-of-the-paris-agreement/.

[100] Mark McKenzie, *Key Outcomes of COP25*, KPMG (Dec. 2019), https://home.kpmg/xx/en/home/insights/2019/12/key-outcomes-of-cop25.html.

[101] Nat Keohane (@NatKeohane), TWITTER (Dec. 14, 2019, 9:59 PM), https://twitter.com/NatKeohane/status/1206061307994267650?s=20.

[102] *Id.*; Lambert Schneider et al., *Outside in? Using International Carbon Markets for Mitigation Not Covered by Nationally Determined Contributions (NDCs) Under the Paris Agreement*, 20 CLIMATE POL'Y 18 (2019), https://www.tandfonline.com/doi/pdf/10.1080/14693062.2019.1674628?needAccess=true (discussing the "outside"/ "inside" NDC distinction mentioned in the Keohane tweet).

[103] Nat Keohane, *COP 25: The Mess in Madrid – and How International Carbon Markets Can Still Drive Ambition Despite It*, ENVT'L DEF. FUND CLIMATE 411 BLOG (Dec. 16, 2019), http://blogs.edf.org/climate411/2019/12/16/cop-25-international-carbon-markets-can-still-drive-ambition-despite-lack-of-article-6-rules/.

[104] Kizzier, *supra* note 99.

[105] *Id.*

the new Paris Agreement system.[106] The problem with such a grandfathering system is that it would count as current mitigation credits which do not in fact reduce carbon emissions today.[107] This would introduce Enron climate accounting by giving current credit for progress for something which is actually status quo.[108]

As Professor Diane Desierto elegantly submits, the failure of COP25 "to achieve the necessary global decisions to implement Article 6 of the Paris Agreement on the creation of an international carbon trading system points to some glaring structural—and not just political—deficits in the international system."[109] The structural problem lies in a popular understanding that the Paris Agreement does not impose substantive legal obligations. As it stands, decarbonization is a voluntary achievement and not a legally compelled duty to comply with nationally determined contributions. As Professor Desierto explains, this perceived voluntary nature of the substantive provisions of the Paris Agreement is legally flawed—the Paris Agreement at a minimum requires states to negotiate in good faith towards the achievement of Paris targets.[110]

Professor Desierto submits that states have failed comply with their mitigation obligations at COP25 in a legally actionable manner.[111] Most notably, states have attempted to double-count emissions in the carbon market, and this represents a failure to negotiate in good faith as required by the Paris Agreement.[112] Such double counting defeats the purpose of Article 6 of the Paris Agreement—a provision that expressly seeks to limit such a scheme.[113] To negotiate a scheme expressly prohibited by the agreement constitutes bad faith.[114]

In addition, the Enron climate accounting proposed by the COP25 holdouts is inconsistent with Article 4 of the Paris Agreement. Article 4(1) combined with Article 4(2) requires states to reduce emissions.[115] This reduction of emissions in each nationally determined contribution "will represent a progression beyond the Party's then current nationally determined contribution and reflect its highest possible ambition"

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106 Leslie Hook, *UN Climate Talks Stymied by Carbon Markets' 'Ghost from the Past'*, INSIDE CLIMATE NEWS (Dec. 16, 2019), https://insideclimatenews.org/news/16122019/cop25-carbon-markets-un-climate-talks-fail-madrid-kyoto-protocol.

107 *Id.*

108 *See id.*

109 Desierto, *supra* note 9.

110 *Id.*

111 *Id.*

112 *Id.*

113 *Id.*

114 *Id.*

115 Paris Agreement, *supra* note 8, at arts. 4(1), (2).

according to Article 4(3).[116] To meet this obligation, Article 4(13) provides that "Parties shall account for their nationally determined contributions [ . . . ] and ensure the avoidance of double counting."[117]

Enron climate accounting violates this rule as it implies that states have a right to increase emissions beyond nationally determined contribution if they cannot sell their Kyoto carry-over credits. States already did not have a right to increase their emissions if they were unable to receive payment for the carry-over credits as is. Such conduct would at least be inconsistent with the obligations set out in Article 4(1)-(3). In fact, it would violate the procedural obligation in Article 4(8) that "all Parties shall provide the information necessary for clarity, transparency and understanding"[118] because this obligation is subject to the prohibition on double counting.[119] The claim that a state has a right to increase emissions proportionate to its banked carry-over credits would not clearly communicate necessary information because the intention to bank Kyoto carry-over credits for use in a yet-to-be-established Article 6 mechanism is unclear. It is unclear precisely because it counts the same emission reduction twice—once in the net total of emissions reduction claimed in the NDC and once in the credit to be banked. To be blunt, a claim such as the one advanced by the COP25 holdouts suggests that the original NDCs were communicated under false pretenses and thus in violation of Article 4.

The fact that states would choose to act with such a lack of good faith at COP25, however, also laid bare an additional but related structural problem. So far, the focus has been on the need for a climate *enforcement* mechanism to hold states accountable to their goals.[120] This enforcement mechanism would bring about compliance with Paris goals by holding states responsible for violation of international legal rules.[121] Domestic courts and human rights bodies have begun down this road,[122] though what goes together with this rule- and enforcement-based focus is a facilitative solution from the impasse.[123]

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[116] *Id.* at art. 4(3).
[117] *Id.* at art. 4(13).
[118] *Id.* at art. 4(8).
[119] *Id.* at art. 4(13).
[120] Desierto, *supra* note 9.
[121] *See* PHILIPPE SANDS & JACQUELINE PEEL, PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW 174-76 (4th ed. 2018) (discussing enforcement mechanisms in the Kyoto context).
[122] Frederic G. Sourgens, *Climate Governance Networks*, *in* DECARBONIZATION IN THE ENERGY INDUSTRY (Tade et al. eds., forthcoming 2020).
[123] SANDS & PEEL, supra note 121, at 174-76.

Climate law has been an early champion of *facilitative* approaches to compliance:[124] those that seek to assist states in finding ways to comply with their climate commitments.[125] With this facilitative perspective in mind, COP25 highlighted two related problems inherent in the current climate regime, one of which can be solved through the appropriately aggressive use of available enforcement mechanisms, but the other of which cannot.

First, states used the under-performance of emission mitigation and climate finance commitments by other countries (principally leading emitters) as a reason to dampen their own ambition.[126] One could cast this first reason as a failure of trust induced by defection by the U.S. and Australia from the Paris framework.[127] A robust enforcement mechanism addresses this failure of trust and thus encourages current defectors to resume their ambition under the expectation that their reliance interests in the U.S. were not misplaced.[128]

But second, there appears to be a larger problem looming behind leading GHG emitters balking at providing appropriate climate financing and carry-over Kyoto carbon credit holders refusing to give up their credits without payment. This problem is that climate financing and carbon mitigation markets can more than double current climate conservation efforts,[129] and the conduct of both groups of states to bypass this potential gain therefore appears as irrational as it is illegal.

But this appraisal ignores the social and economic costs of upending current energy infrastructure, both for industry and consumers. The bad faith positions of each group of states—leading emitters and carry-over credit holders—suggest that the rate of mitigation is too steep to absorb without massive social costs. Both groups of states appear unwilling or unable to shoulder these costs.[130] To be sure, this is not a sound *legal* justification for defying international legal obligations, but it is a central consideration for designing markets that can actually facilitate compliance with those obligations.

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124 *Id.*

125 *Id.*

126 Hood, *supra* note 93.

127 *See* Sourgens, *supra* note 88, at 1652.

128 Desierto, *supra* note 9.

129 Keohane, *supra* note 103.

130 For a discussion of the unwilling and unable doctrine in the international law of armed conflict, *see* Craig Martin, *Challenging and Refining the "Unwilling or Unable" Doctrine*, 52 VAND. J. TRANSNAT'L L. 387 (2019). For a discussion of climate mitigation (or its failure) as a cause for war, *see* Craig Martin, *Atmospheric Intervention: Climate Change and the Jus ad Bellum Regime*, COLUM. J. ENVNT'L L. (forthcoming, 2020) (on file with the author).

This second and more worrying structural lesson from COP25 finds support in the recent *Urgenda* proceedings in the Netherlands.[131] *Urgenda* involved one of the first successful climate lawsuits in a domestic court.[132] The Hague district court ruled for the plaintiffs and found that the Dutch government's climate policy was inadequate under the Dutch Civil Code and an appellate court later ruled that the Dutch policy failed to meet human rights demands under the European Convention on Human Rights.[133] The Supreme Court of the Netherlands recently affirmed the judgment.[134] Overall, the litigation was hailed as a major victory for climate activists and showcased the promise of enforcement actions under existing law.[135]

But at the same time, cases like *Urgenda* also show the limits of the current enforcement regime. The Dutch government responded to *Urgenda* tepidly.[136] It did not outright refuse to comply,[137] but no tangible improvements to Dutch climate and energy policy are on the way to meet the court-ordered emissions cut.[138] If this is the response of the government of the Netherlands to a judgment affirmed by its own highest court, one wonders what chance such actions have to lead to quick changes in policy in other jurisdictions, particularly those violating their international legal obligations made at COP25.

To solve the structural problems rearing their head at COP25, one must be able to force the Paris parties back to the table to honor their commitments by implementing a meaningful carbon trading market. But this first step only works, or only works in the short window permitted by the current climate crisis, if there is a feasible path to designing a Paris-

131 For all source documents on this lawsuit, see *The Urgenda Climate Case Against the Dutch Government*, URGENDA.NL, https://www.urgenda.nl/en/themas/climate-case/ (last visited Jan. 3, 2020).

132 *Comparative Law-Climate Change-Hague Court of Appeal Requires Dutch Government to Meet Greenhouse Gas Emissions Reductions by 2020.-Hof's-Gravenhage 9 Oktober 2018, Ab 2018, 417 M.nt. Ga Van Der Veen, Ch.w. Backes*, 132 HARV. L. REV. 2090, 2092-3 (2019).

133 *Id.* For a broader perspective on such suits, *see* Jacqueline Peel & Jolene Lin, *Transnational Climate Litigation: The Contribution of the Global South*, 113 AM. J. INT'L L. 679 (2019).

134 Urgenda, *supra* note 131.

135 John Schwartz, *In 'Strongest' Climate Ruling Yet, Dutch Court Orders Leaders to Take Action*, N.Y. TIMES, (Dec. 20, 2019), https://www.nytimes.com/2019/12/20/climate/netherlands-climate-lawsuit.html.

136 *See* Isabella Kaminski, *Dutch Supreme Court Upholds a Landmark Ruling Demanding Climate Action*, GUARDIAN (Dec. 20, 2019), https://www.theguardian.com/world/2019/dec/20/dutch-supreme-court-upholds-landmark-ruling-demanding-climate-action; *Netherlands Climate Change: Court Orders Bigger Cuts in Emissions*, BBC (Dec. 20, 2019), https://www.bbc.com/news/world-europe-50864569 (noting that "the chances of the government reaching the [court-ordered] target look slim").

137 Kaminski, *supra* note 136.

138 BBC, *supra* note 136.

compliant market that lessens the political and social costs of implementing it in the first place. Short of such a plan, one can expect recalcitrant nations to quote President Andrew Jackson: "John Marshall has made his decision; now let him enforce it."[139]

### *D. The Paris Carbon Removal Assumption*

All of this means that, Paris Agreement or not, the world is looking at a cognizable achievement gap that must be closed in the near future to avoid the IPCC's warning of potential climate tipping points ahead. Specifically, review of the pledges made pursuant to the Paris Agreement reveal that States have not pledged a reduction in GHG emission to meet even the less ambitious 3.5°C target.[140] This overshoots the anticipated warming tipping point by 1.5°C to 2°C even in an optimistic setting.[141] Since states are under-performing their nationally determined contributions, the achievement gap is likely more significant still than the Paris Agreement pledges suggest.[142]

This overshoot can be expressed in the annual surplus amount of $CO_2$ equivalent GHGs that would still need to be removed under current parameters: approximately 17.995 gigatons by 2030.[143] To translate, a gigaton is one billion tons.[144] and, this weight is the equivalent of more than 100 million elephants.[145] Meredith Nettles of the Lamont-Doherty Earth Observatory used a different analogy to visualize this weight: you could store a gigaton of ice "if you took the whole National Mall, and covered it up with ice, to a height about four times as high as the [Washington] monument, [ . . . ] [a]ll the way down from the Capitol

139 *See* Justice Stephen Breyer, *University of Pennsylvania Law School Commencement Remarks*, SUPREMECOURT.GOV (May 19, 2003), available at https://www.supremecourt.gov/publicinfo/speeches/viewspeech/sp_05-19-03.

140 IPCC, *supra* note 4, at 56.

141 *Id.* at 8.

142 Wernick, *supra* note 84.

143 To explain, IPCC suggests that to avoid tipping elements, emissions must "decline by about 45% from 2010 levels by 2030." IPCC, *supra* note 4, at 14. Expressed in gigatons, this means emissions of 18.205 gigatons (or 55% of 33.1 gigatons); *see* Kelly Levin, *New Global CO2 Emissions Numbers Are In. They're Not Good*, WORLD RESOURCE INST. (Dec. 5, 2018), https://www.wri.org/blog/2018/12/new-global-co2-emissions-numbers-are-they-re-not-good (calculating current carbon emissions in gigatons). Currently, global carbon emissions are 36.2 gigatons. The difference between current emissions and the target is 17.995 gigatons.

144 Chris Mooney, *To Truly Grasp What We're Doing to the Planet, You Need to Understand This Gigantic Measurement*, WASH. POST (July 1, 2015), https://www.washingtonpost.com/news/energy-environment/wp/2015/07/01/meet-the-gigaton-the-huge-unit-that-scientists-use-to-track-planetary-change/?utm_term=.a54069922b01.

145 *Id.*

steps to the Lincoln Memorial."[146] These annual amounts of surplus emissions are thus serious no matter how one looks at them.

For the Paris Agreement to work in light of the current slow start and the ticking bomb conjured by the IPCC's most recent climate report, these $CO_2$ emissions will have to be removed somehow. This removal will likely require new technology, and it will also be expensive.

To make matters worse, some low-hanging mechanisms that could assist in $CO_2$ removal or capture have already been built into the currently under-performing nationally determined contributions. The Paris Agreement pledges already assume as a baseline that countries will mitigate net GHG emissions not only through emissions reductions but also by removing GHGs (mostly $CO_2$) from the atmosphere by means of "sinks."[147] $CO_2$ sinks include, for example, forests that capture $CO_2$ through photosynthesis.[148] As Benoit Mayer notes, the use of sinks to meet nationally determined contributions under the Paris Agreement is a common compliance technique.[149]

This problem becomes more acute when it is decided how much emissions should be reduced to make up the difference between the current Paris Agreement pledges and the temperature goal of the Paris Agreement.[150] This difference would require an *additional* ability to remove billions of tons of GHGs from the atmosphere beyond what states already anticipated they would be able to contribute as part of their nationally determined contributions. Even if afforestation and similar processes could in theory meet the demand for sinks in nationally determined contributions, it would be a stretch to say this could also meet the additional need for carbon removal.

In any event, the mitigation-by-reduction approach has practical limits. It is simply not plausible to assume that one can do a global "energy swap" from fossil fuel burning to alternative energy in just a couple of years. Even in a country that is aggressive towards promoting solar energy, the process from planning to commercial operations for a single solar power project can still take four years.[151] Wind, and particularly offshore wind, take longer still to develop.[152] The average construction

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146 *Id.*

147 MAYER, *supra* note 11, at 158.

148 BODANSKY ET AL., *supra* note 64, at 55.

149 MAYER, *supra* note 11, at 158.

150 IPCC, *supra* note 4, at 56.

151 Masdar Solar & Wind Cooperatief U.A. v. Spain, ICSID Case No. ARB/14/1, award (May 16, 2018), ¶¶ 82-99.

152 *Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2019*, EIA (Jan. 2020), https://www.eia.gov/outlooks/aeo/assumptions/pdf/table_8.2.pdf

time for a nuclear power plant is approximately 7-8 years (and that does not include the time spent in the planning and financing phases).[153] Even if there was an immediate demand increase for licensing and construction sufficient to swap out all existing fossil fuel burning power plants, this time is likely to increase not decrease. Any plan to decarbonize therefore is not realistic in the 2030 timeframe set out by the IPCC.[154]

This timeframe problem for an energy infrastructure swap is on full display in the current political environment, even among supporters of decarbonization. For example, in the summer of 2019 the newly elected Finnish Parliament pledged to become carbon neutral by 2035.[155] Considering the scales to which more populous and geographically larger states would have to mobilize to make a similar pledge, a realistic date would look to no earlier than 2050 or later, even assuming the political will to act now—a political will which, reportedly, is not even assured within the ranks of the U.S. Democratic Party that is supportive of climate action.[156]

This reality check is even more glaring in the transportation sector. Assuming that every Paris Agreement member state banned the sale of new fossil fuel-burning cars today, the last fossil fuel burning cars could be expected to still be on the road for between 11 and 18 years.[157] Moreover, there is no serious move to pass such a ban outside of Europe,[158] and many European plans to ban the sale of new cars with combustion engines are not slated to take effect until 2040.[159] Therefore,

(setting out the shortest possible construction times for various types of power plants in the U.S. under ideal conditions).

153 Pedro Carajilescov & João M. L. Moreira, *Construction Time of PWRs*, 2011 INT'L NUCLEAR ATLANTIC CONF. - INAC 2011, available at https://inis.iaea.org/collection/NCLCollectionStore/_Public/42/105/42105221.pdf.

154 IPCC, *supra* note 4.

155 Jon Henley, *Finland Pledges to Become Carbon Neutral by 2035*, GUARDIAN (June 4, 2019), https://www.theguardian.com/world/2019/jun/04/finland-pledges-to-become-carbon-neutral-by-2035.

156 *See* Jeff Stein & Dino Grandoni, *Elizabeth Warren Proposes $2 Trillion Clean Energy Plan as Green New Deal Momentum Builds*, WASH. POST (June 4, 2019), https://www.washingtonpost.com/us-policy/2019/06/04/elizabeth-warren-proposes-new-department-economic-development-elimination-commerce-department/?utm_term=.f7105347cecf (noting labor concerns); Jeff Stein & Dino Grandoni, *Joe Biden Embraces Green New Deal as He Releases Climate Plan*, WASH. POST (June 4, 2019), https://www.washingtonpost.com/climate-environment/2019/06/04/joe-biden-embraces-green-new-deal-he-releases-climate-plan/?utm_term=.8499550344ea (promising 2050 as the date for a carbon neutral energy sector).

157 Michael J. Coren, *Nine Countries Say They'll Ban Internal Combustion Engines. So Far, It's Just Words*, QUARTZ (Aug. 7, 2018), https://qz.com/1341155/nine-countries-say-they-will-ban-internal-combustion-engines-none-have-a-law-to-do-so/.

158 *Id.*

159 *Id.*

the transportation industry is not able to meet mitigation goals in a fast and efficient manner even when there is political will to try.

Thus, the Paris Agreement must tacitly assume that the world will find a way to remove large amounts of GHGs from the atmosphere and store them safely if we are to reach the stated goal of halting global warming at all. Without this ability, the recent IPCC report suggests that triggering climate tipping elements will become unavoidable no matter how far the world cuts back global GHG emissions. Without significant carbon removal, the goals set forth in Paris would have failed before the first set of nationally determined contributions had even been fully implemented.

Critically, the Paris Agreement does not provide a clear mechanism for how such carbon removal could be achieved. While the Paris Agreement is broadly consistent with a market-based approach to carbon mitigation and carbon removal, it does not currently provide a means to develop or deploy carbon removal technology.[160] The Paris Agreement also discusses, in broad terms, how climate financing could be made to function,[161] though it does not provide a carbon-removal specific mechanism in this respect.[162]

The three relevant provisions in the Paris Agreement are permissive of carbon removal technology,[163] but no provision sets out a plan to take the world from point A of no such technology to point B of deploying such a technology to remove billions of tons per year in the short time frame required to prevent catastrophic climate change. Post-Paris meetings in Berlin and Katowice continue this trend of setting up rules that are broadly consistent with a carbon removal market,[164] but they do not set up a mechanism that would bring it into being anywhere fast enough to be effective.

## II. THE COMMONS SWITCH

This is not to say that all is lost. There is a tangible and momentous effort to address climate change by actors outside of the governmental sector. When the likes of ExxonMobil and Shell are not only proponents of the Paris Agreement but active investors in alternative energy, it

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160 BODANSKY ET AL., *supra* note 64, at 236-37.

161 ZAHAR, *supra* note 66, at 72-74.

162 *See id.*

163 MAYER, *supra* note 11, at 158.

164 For early analysis of progress at Katowice, *see* Frederic G. Sourgens, *Paris Agreement Regained or Lost? Initial Thoughts*, EJILTALK! (Dec. 28, 2018), https://www.ejiltalk.org/paris-agreement-regained-or-lost-initial-thoughts/; Chrysa Alexandraki, *COP 24 and Climate Finance: A Stepping Stone or a Blurred Line?*, EJILTALK! (Jan. 23, 2019), https://www.ejiltalk.org/cop-24-and-climate-finance-a-stepping-stone-or-a-blurred-line/.

becomes clear that the winds have meaningfully shifted in favor of taking climate change very, very seriously.[165] Publicly listed companies have begun to assign anticipated losses to climate change, with some 200 leading public companies currently projecting losses at $1 trillion over the next five years: there is a business case for mitigation.[166] Further, there has been significant movement towards mitigation in rapidly industrializing countries such as China without which the fight against global warming would be hopeless.[167] The sovereign wealth funds of oil producing countries such as the United Arab Emirates and Saudi Arabia are similarly making significant pushes to diversify into alternative energy.[168]

This evidence suggests that more can be done to combat climate change than current legal institutional designs anticipate. In particular, there is a growing interest and awareness in the subject by businesses, energy companies, and the sovereign wealth funds of major oil exporters. The current institutional design does not permit to bring these actors directly into efforts to slow, halt, and reverse climate change.[169] But given the urgency outlined in the IPCC report, this is an institutional design problem that must be addressed as quickly as possible.[170]

From an institutional design perspective, the problem is that the current institutions used fight climate change are the result of an environmental law paradigm.[171] This environmental law paradigm is state-centered and does not fully harness all actors who could be leveraged into the fight against climate change.[172] In order to create a broader approach, an energy

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165 *New Energies*, SHELL, https://www.shell.com/energy-and-innovation/new-energies.html (noting $2 billion investment in wind power by Shell); Chris Martin & Kevin Crowley, *Exxon Will Use Wind, Solar to Produce Crude Oil in Texas*, BLOOMBERG (Nov. 28, 2018), https://www.bloomberg.com/news/articles/2018-11-28/oil-giant-exxon-turns-to-wind-solar-for-home-state-operations; *see also* Daniel Farber, *The Conservative as Environmentalist: From Goldwater and the Early Reagan to the 21st Century*, 59 ARIZ. L. REV. 1005, 1045-6 (2017).

166 Matthew Green, *World's Biggest Firms Foresee $1 Trillion Climate Cost Hit*, REUTERS (June 4, 2019), https://www.reuters.com/article/us-climate-change-companies-disclosure/worlds-biggest-firms-foresee-1-trillion-climate-cost-hit-idUSKCN1T50CF.

167 Scott Moore & Michelle Melton, *China's Pivot on Climate Change and National Security*, LAWFARE (Apr. 2, 2019), https://www.lawfareblog.com/chinas-pivot-climate-change-and-national-security.

168 Masdar Solar & Wind Cooperatief U.A., *supra* note 151, at ¶¶ 80-82; Anthony Dipaola & Mahmoud Habboush, *Saudi's Sovereign Fund to Invest in Giant Clean Power Unit*, BLOOMBERG (Jan. 15, 2019), https://www.bloomberg.com/news/articles/2019-01-15/saudi-s-sovereign-fund-to-develop-most-of-kingdom-s-clean-power.

169 For a helpful summary of the existing literature on polycentric climate governance, s*ee* Marcel J. Dorsch & Christian Flachsland, *A Polycentric Approach to Climate Governance*, 17 GLOBAL ENVIRONT'L POL. 45, *passim* (2017).

170 IPCC, *supra* note 4, at 56.

171 SANDS & PEEL, supra note 121, at 299-318; BODANSKY ET AL., supra note 64, at 55.

172 *See* SANDS & PEEL, supra note121, at 299-318.

paradigm must be brought in to compliment the current environmental paradigm. This energy paradigm will offer a roadmap for how to construct a marketplace in which carbon removal technology could be broadly developed and deployed to achieve the goals of climate change mitigation.

### *A. The Environmental Paradigm*

Current climate change law frames the issue through the lens of international environmental law.[173] In particular, as a matter of historical development, climate change became a concern of international lawyers at the same time, or slightly after, efforts to curb the depletion of the ozone layer in the late 1980s to early 1990s.[174] Global efforts to halt the emission of gases that destroyed the ozone layer—the Vienna Convention of 1985 and the Montreal Protocol—proved to be a great success at bringing together the global community to protect the atmosphere.[175] These treaties were essentially environmental treaties,[176] and the effort to address climate change was largely seen as following in the same footsteps.[177]

The efforts to develop a response to climate change then was included in the leading international environmental law agenda, the UN Conference for Environment and Development ("UNCED") and its 1992 Rio Summit.[178] The UNCED and the Rio Summit dealt with climate change through the lens of the broader development of international environmental law.[179] The UNCED eventually implemented climate change efforts through the 1992 UNFCCC,[180] as well as in its Kyoto Protocol,[181] and now in the Paris Agreement adopted pursuant to the UNFCCC.[182] This means that, as a general rule, international climate change efforts follow international environmental law principles.[183]

The first and most important cluster of international environmental law principles applied to climate change is the no harm principle, in combination with the precautionary principle.[184] The no harm principle

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173 *Id.*
174 BODANSKY ET AL., supra note 64, at 98-99.
175 *Id.* at 14, 98-99.
176 *Id.*
177 *Id.*
178 *See* SANDS & PEEL, *supra* note 121, at 299.
179 BODANSKY ET AL., *supra* note, at 102.
180 *Id.*
181 *Id.* at 105-08.
182 *Id.* at 110-15.
183 *Id.* at 40-55; SANDS & PEEL, *supra* note 121, at 197-250; MAYER, *supra* note 11, at 72-76.
184 *See* BODANSKY ET AL., *supra* note 64, at 43, 53; MAYER, *supra* note 11, at 73.

provides that "[s]tates must prevent activities within their territory or control from causing serious transboundary harm."[185] This principle is typically combined with the precautionary principle as the no-harm rule "has its origins in the due diligence that is required of a State in its territory."[186] In turn, the precautionary principle dictates what diligence a state must take when there is scientific uncertainty about potentially serious transboundary harms.[187]

The precautionary principle provides that the lack of scientific certainty as to the potentially serious effects of climate change should not halt efforts to take preventative action.[188] International environmental law in particular looks to the precautionary principle as a reason to drastically mitigate GHG emissions so as to avoid "the cataclysmic risk of a climate runaway scenario."[189] The precautionary principle becomes more problematic in the context of affirmative measures such as geoengineering that themselves could have negative environmental impacts.[190] Environmental lawyers in that context use the precautionary principle to advocate significant caution in the adoption of new technological approaches even if these new technological approaches would stand to address the overall risk of climate change.[191] In other words, as an environmental law principle, the precautionary principle counsels (and requires) mitigation and reduction in pollution and the development of counter-measures to deal with existing emissions even if only as a means of last resort.[192]

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185 MAYER, *supra* note 11, at 66.

186 BODANSKY ET AL., *supra* note 64, at 41 (internal quotation marks omitted).

187 *Id.* at 42-43.

188 *See id.* at 53-55 (applying the precautionary principle to sustainable development). For further discussion of the precautionary principle, *see* SANDS & PEEL, *supra* note 121, at 229-40; JACQUELINE PEEL, SCIENCE AND RISK REGULATION IN INTERNATIONAL LAW 129-54 (2010); CAROLE E. FOSTER, SCIENCE AND THE PRECAUTIONARY PRINCIPLE IN INTERNATIONAL COURTS AND TRIBUNALS: EXPERT EVIDENCE, BURDEN OF PROOF AND FINALITY 18-21 (2011).

189 MAYER, *supra* note 11, at 73.

190 *See id.* at 155.

191 *See* Ralph Bodle, *Geoengineering and International Law: The Search for Common Legal Ground*, 46 TULSA L. REV. 305, 311 (2013) (noting that "[t]he role of the precautionary principle . . . in the geoengineering debate remains ambiguous"); Karen N. Scott, *International Law in the Anthropocene: Responding to the Geoengineering Challenge*, 34 MICH. J. INT'L L. 309, 341-44 (2013) ("The nature, and indeed the extent, of the environmental risks associated with geoengineering could potentially justify a moratorium on the deployment of, or even research into, these techniques and technologies. However . . . geoengineering constitutes a response to, and an attempt to mitigate, a serious risk of environmental harm: climate change."); *but see* Reynolds, *supra* note 13, at 126 (arguing that "precaution as embodied in the UNFCCC, calls at least for consideration, such as through research, of all means to reduce climate change risks, including that of climate engineering").

192 *See, e.g.*, GARDINER, *supra* note 46, at 339-396; HAMILTON, *supra* note 55, at 174; Bodle, *supra* note 191, at 311.

Another important international environmental law principle applied in the context of climate change is that polluters should pay.[193] This principle "supports the view that polluters should be charged a fee that would dissuade them from pollution whenever it is likely to disincentivize pollution."[194] Professors Sands and Peel caution that "[s]tate practice does not support the view that all the costs of pollution should be borne by the polluter, particularly in interstate relations."[195] Nevertheless, others such as Professors Michael Faure and Andre Nollkaemper have articulated theories of how a failure to abide by relevant diligence duties or treaty obligations could give rise to international liability and thus operationalize the polluter pays principle in international climate law.[196]

These environmental law principles create at least some tension with, if not an outright adversarial relationship between, the value of environmental sustainability on the one hand and economic and social development on the other. The tension is prominently on display in the context of the precautionary principle. The precautionary principle in international environmental law requires the cessation of certain economic activity even if a cost-benefit analysis cannot be fully substantiated.[197] It operates on the principle that, in case of doubt, economic activity should take a backseat to environmental protection.[198] An economic development perspective would take the opposite point of view and would require that society should abstain from regulations that may have negative impacts on the economic growth needed to create and support dignified living conditions.[199] It would submit that environmental concerns should only be taken into account as part of "a balanced and integrated economic and social development" because this development "contribute[s] toward the promotion and maintenance of peace and security, social progress and better standards of living, and the observance of, and respect for, human rights and fundamental freedoms for all."[200]

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193 *See* MAYER, *supra* note 11, at 74-75.

194 *Id*. at 74.

195 SANDS & PEEL, *supra* note 121, at 244.

196 Michael G. Faure & André Nollkaemper, *International Liability as an Instrument to Prevent and Compensate for Climate Change*, 26A STAN. ENVTL. L.J. 123, 140-42, 145 (2007).

197 *See* PEEL, *supra* note 188, at 111-70.

198 *See* GARDINER, *supra* note 40, at 402, 412-14; SANDS & PEEL, *supra* note 121, at 229-40.

199 *See* SANDS & PEEL, *supra* note 121, at 230 (noting the objection to the precautionary principle as over-regulation stifling economic growth).

200 G.A. Res. 1161 (XII), Balanced and Integrated Economic and Social Progress (Nov. 26, 1957). For a discussion on the link between social, economic, and human rights, *see* DIANE DESIERTO, PUBLIC POLICY IN INTERNATIONAL ECONOMIC LAW, THE ICESCR IN TRADE, FINANCE, AND INVESTMENT 68-76 (1st ed. 2015) (outlining the key features of the International

The same tension also applies to at least a strong version of the polluter pays principle.[201] The strong version of the principle has as its ultimate goal "to eliminate [] pollution,"[202] and it does not seek to compensate those affected for the effects of pollution; it seeks to create disincentives for environmentally harmful activity no matter how economically beneficial that activity may be.[203] Actors with an economic development perspective may view pollution as an externality the cost of which should be borne by society at large because of its economically and socially beneficial impact, and these actors would thus not seek to disincentivize the activity for developmental reasons.[204]

This adversarial relationship plays out in terms of climate equity, which involves the right of developing states to industrialize and improve living conditions. Both the polluter pays principle and the precautionary principle would increase the economic burden of development and thereby make industrializing countries and transitional economies less competitive in the global marketplace.[205] This hides from view the truly salutary *social* implications of globalization and (carbon intensive) global supply chains. As David Pilling noted in his otherwise growth-critical book, *The Growth Delusion*, economic globalization created a global middle class in places that previously lacked one.[206] It thus creates the kind of living conditions consistent with meaningfully increasing opportunities for a dignified life around the world.[207]

It is crucial that the world's developing countries, known as the G-77, are viewed through a developmental lens with the principle of differentiation in mind.[208] This principle provides in its starkest form that developing economies must be exempt from the climate mitigation regime in order to be differentiated from developed countries.[209] It thus

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Covenant on Economic, Social and Cultural Rights ("ICESCR")). These concerns include the right to a healthy environment as one of the constitutive socio-economic factors to be taken into account. *See id.* at 213.

201 SANDS & PEEL, *supra* note 121, at 240-44 (outlining the different versions of the principle as referenced in various international instruments).

202 *Id.* at 242 (quoting approvingly the EU position).

203 MAYER, *supra* note 11, at 74.

204 For a discussion of such a debate in the economics literature, *see* GARDINER, *supra* note 46, at 257-65 (discussing the DICE and Stern modelling controversy regarding climate change economics).

205 *See* SANDS & PEEL, *supra* note 121, at 246-48 (discussing the concept of "differentiated responsibility of states for the protection of the environment").

206 DAVID PILLING, THE GROWTH DELUSION: WEALTH, POVERTY, AND THE WELL-BEING OF NATIONS 96 (2018).

207 MARTHA NUSSBAUM, CREATING CAPABILITIES: THE HUMAN DEVELOPMENT APPROACH 30-34 (2011)

208 *Id.*

209 BODANSKY ET AL., *supra* note 58, at 26-30.

protects the ability of G-77 countries to create and maintain the economic conditions necessary to bring about the emergence of the middle class noted by Pilling.[210]

Given the current pressure to mitigate GHG emissions and the short window of time in which it could be done to avoid climate tipping points, the principle of differentiation is patently unworkable.[211] For that reason it has been softened significantly in recent environmental negotiations like the non-binding Copenhagen agreements and the Paris Agreement.[212] This, however, did little to rectify the developmental problems created by adopting an environmental framework in the first place, particularly as climate finance is slow to materialize and even slower to provide the funding needed for adaptation measures.[213]

This adversarial relationship between an environmental and a developmental perspective also plays out in developed countries such as the U.S., France, and Australia, albeit on a different scale. The U.S. has experienced a significant regression in living standards (financially and socially) particularly for rural and blue-collar communities.[214] This regression is associated on the one hand with the opioid epidemic,[215] and it is also associated with the rise of populism in U.S. politics.[216] Importantly, the policy positions historically adopted by champions of climate change mitigation had the negative side effect of disproportionately targeting what felt like the remaining opportunities for these very communities.[217]

In France, the same phenomenon is on full display after the attempts by the Macron government to meet its Paris Agreement commitments through a carbon tax.[218] This approach is consistent with the polluter pays principle as it seeks to disincentivize the use of fossil fuels by making the use such energy sources more expensive and thus less desirable compared

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210 PILLING, *supra* note 160, at 96.

211 *See* IPCC, *supra* note 4, at 56 (outlining the dire climate situation).

212 ZAHAR, *supra* note 60, at 13-15.

213 *Id.* at 101-12.

214 PILLING, *supra* note 160, at 93.

215 *Id.* at 91-92.

216 *Id.* at 93.

217 Eliza Relman, *Hilary Clinton: Here's the Misstep from the Campaign I Regret the Most*, BUS. INSIDER (Sept. 6, 2017), https://www.businessinsider.com/hillary-clinton-biggest-campaign-mistake-2017-9 (discussing the electoral implication of Secretary Clinton's statement at a town hall that "she would put coal miners out of business.").

218 Steven Mufson & James McAuley, *France's Protesters Are Part of a Global Backlash Against Climate-Change Taxes*, WASH. POST (Dec. 4, 2018), https://www.washingtonpost.com/world/europe/frances-protesters-are-part-of-a-global-backlash-against-climate-change-taxes/2018/12/04/08365882-f723-11e8-863c-9e2f864d47e7_story.html?utm_term=.1469519fa347.

to other forms of energy consumption.[219] However, this approach disproportionately affects lower income rural or commuting communities.[220] This unintended consequence directly led to yellow vest protests in France.[221]

Australia provides another recent example of a similar phenomenon. In an election dubbed the country's "climate election," the conservative candidate for prime minister prevailed even though he was openly against climate mitigation measures.[222] For context, Australia is one of the world's leading exporters of coal, and the election could be thought of as aligning with the economic and industry interests present in the country.[223] The argument that climate mitigation measures are too expensive thus dovetails with the appeal of President Donald Trump in the coal mining communities of West Virginia and parts of Pennsylvania.[224]

It is therefore uncharitable to describe the current ethical crisis posed by climate change as one of juxtaposing luxuries now in exchange for crippling environmental costs passed down to future generations. This is the account of the leading ethical analysis of climate inaction as articulated in Stephen Gardiner's *A Perfect Moral Storm.*[225] This account is uncharitable because it obscures the fact that more than just the luxury class is opposed to climate change mitigation.[226] Rather, one might theorize that the current approaches to climate change mitigation (or at the very least, the manner of their implementation) disproportionately affect groups in society that were only recently able to enjoy the full benefits of policies that improve living conditions. The current paradigm therefore forces choices that may be significantly more tragic than leading minds in climate ethics literature would acknowledge.[227]

This, paradoxically, would be a positive point. It would allow one hypothesis to be proven: the disconnect between the climate change threat and the apathy towards a response is caused partially by the narrow institutional design change under which policy operates. This would mean that a different institutional design may be able to unlock

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[219] MAYER, *supra* note 6, at 74, 124.

[220] Mufson & McAuley, *supra* note 172.

[221] *Id.*

[222] Cave, *supra* note 83.

[223] Martin Farrer, *Australia's Mining Exports Hit $278bn – But Bonanza at Risk, Says Report*, GUARDIAN (Mar. 29, 2019), https://www.theguardian.com/environment/2019/mar/29/chinas-policies-put-australias-5bn-coal-export-earnings-at-risk.

[224] Walter E. Block, *Stop Trying to Make Coal Great Again*, N.Y. TIMES (June 4, 2019), https://www.nytimes.com/2019/06/04/opinion/trump-coal.html.

[225] GARDINER, *supra* note 40.

[226] *Id.*

[227] *Id.*; HAMILTON, *supra* note 49.

significant additional synergies in the fight against climate change. As it stands, leading politicians advocating for aggressive climate action tacitly admit to this necessity by promoting proposals as the "Green New Deal" through both environmental and developmental lenses.[228] A "Green New Deal" seeks to marry both environmental protections and economic opportunity for historically marginalized communities.[229]

The problem from a design perspective is that the broadening of the climate paradigm has not been appropriately theorized. Most importantly, current approaches are largely state-driven and rely upon taxation as the main means of funding climate action.[230] This approach remains trapped, to a point, in the environmental paradigm because it looks to the state as the principal source of necessary funding to bring about a green revolution. It would seek to change the manner in which the state raises revenue for this project, to be sure.[231] But it would not change the manner in which the problem is tackled.

The remainder of this Article will submit that it is possible to broaden the approach further than that. It will argue that a paradigm switch from an environmental perspective permits actors to look to the marketplace to become a fully engaged, providing significant financial leverage. Intuitively, it will be by freeing up this additional capital and employing additional leverage that the gap between ambition and implementation can best be closed. If the state so far has failed to close the gap on its own, it is natural to look for an ally to assist in closing the gap. A paradigm switch would achieve this goal.

### B. *The Energy Paradigm*

Climate activists bristled at the suggestion by then ExxonMobil CEO Rex Tillerson that climate change is an engineering problem.[232] In the search for an alternative paradigm to assist in designing more effective climate change mitigation, Mr. Tillerson's perspective nevertheless is intriguing. It suggests that other important actors might take the next step when an oil and gas company executive treats climate change as an engineering issue to looking to energy law—the law governing many of the results of engineering feats in the energy industry—for inspiration.

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228 *See* Stein & Grandoni (1), *supra* note 110 (discussing Sen. Warren's climate change policy proposal in light of the Green New Deal); Stein & Grandoni (2), *supra* note 110 (discussing Vice President Biden's climate change policy proposal in light of the Green New Deal).

229 *See* citations in note 167.

230 *Id.*

231 *Id.*

232 HAMILTON, *supra* note 49, at 78.

It is important to unpack what an engineering problem entails. Analytically, there are two different types of engineering problems, common resource management problems and purely technological problems. The first problem is familiar to Rex Tillerson and others in the U.S. oil and gas industry: the application of the common law rule of capture to oil ownership caused adjoining mineral rights owners with an interest in the same oil reservoir to overexploit resources so as to avoid losing out to their neighbor.[233] From an engineering perspective, the overexploitation led to a collapse of reservoir pressure that would not have occurred if the parties had developed the common reservoir prudently,[234] and this overexploitation led to waste.[235] Conservation laws have largely taken this engineering insight to heart and now require mineral rights owners to develop reserves to avoid such waste.[236]

The second engineering problem is technical in nature. For example, there are oil and gas reserves that could not have be developed in the late 1990s that are now available because of[237] engineering advances in hydraulic fracturing and horizontal.[238] There is now a technological solution to increasing oil and gas production in the U.S. in "unconventionals," and this kicked off the shale revolution.[239]

Frequently, the two problems are inherently interwoven. Famously, the nineteenth century political economist Thomas Malthus warned that the global ecosystem could only ever support a bounded maximum human population.[240] Malthus's point is one of commons management—there are only so many resources to go around, and overuse will lead to a collapse of these resources.[241] World society has frequently escaped Malthusian predictions of doom through technological advances such as those employed to develop new types of wheat that have be grown to sustain growing populations.[242]

The suggestion to treat climate change as an engineering problem links climate change to the prudent management of the commons and how technology assists in this management to prevent a tragedy of the

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233 James W. Coleman, *The Third Age of Oil and Gas Law*, 95 INDIANA L.J. (forthcoming 2019), available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3367921.

234 *Id.*

235 *Id.*

236 *Id.*

237 Robert Rapier, *How the Shale Boom Turned the World Upside Down*, FORBES (Apr. 21, 2017), https://www.forbes.com/sites/rrapier/2017/04/21/how-the-shale-boom-turned-the-world-upside-down/#29df270877d2.

238 *Id.*

239 *Id.*

240 PILLING, *supra* note 160, at 149-50.

241 *Id.*

242 *Id.*

commons.[243] This "tragedy," as first described by Garrett Hardin, submits that commons management poses significant collective action issues from overuse.[244] To explain the concept, Hardin uses the example of multiple herdsmen using a common grazing pasture.[245] Each additional animal the herdsmen bring to the pasture increases the individual utility for each herdsman (think free food for the animals).[246] Every herdsman naturally will try to increase his or her own herd by as many animals as they can afford.[247] The problem is that each additional animal increases the risk of overgrazing until the eventual collapse of the pasture, leaving all herdsman worse off.[248] Moreover, until all herdsman act collectively to avoid the this collapse, each herdsman is incentivized to get as much out of the common as quickly as possible.[249] Lawyers in Exxon's legal department would have been all too familiar with the tragedy of the commons given the historical overdevelopment of oil and gas reservoirs that lead to substantial waste.[250]

To solve a commons problem is to look for means of collective action that are in the mutual interest of all involved.[251] In the case of climate change, the problem is the oversupply of $CO_2$ and other GHGs.[252] In Malthusian terms, the danger today is that this oversupply will bring about the collapse of global agricultural supply chains and thus the world economy.[253] The problem, however, is that it is not currently possible to power global supply chains without the fossil fuels that have created this oversupply of $CO_2$. This issue cannot be overcome by charging taxes that would disincentivize the emissions for the reason outlined in the previous

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243 Devani G. Adams, *Why We Cannot Wait: Transnational Networks As a Viable Solution to Climate Change Policy*, 13 SANTA CARA J. INT'L L. 307, 324-25 (2015) (describing climate change as a tragedy of the commons); Michele Fink & Sofia Ranchordas, *Sharing and the City*, 49 VAND. J. TRANSNAT'L L. 1299, 1330, n.160 (2016) (same); Blake Hudson & Jonathan Rosenbloom, *Uncommon Approaches to Common Problems: Nested Governance Commons and Climate Change*, 64 HASTINGS L.J. 1273, 1336 (2013) (same); Sarah E. Light, *Precautionary Federalism and the Sharing Economy*, 66 EMORY L.J. 333, 348 (2017) (same); Surabhi Ranganathan, *Global Commons*, 27 EUR. J. INT'L L. 693, 693 (2016) (same); Katharine Trisolini, *All Hands on Deck: Local Governments and the Potential for Bidirectional Climate Change Regulation*, 62 STAN. L. REV. 669, 674 (2010) (same).

244 Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243, 1243-44 (1968).

245 *Id.*

246 *Id.*

247 *Id.*

248 *Id.*

249 *Id.*

250 Jacqueline Weaver, *The Tragedy of the Commons from Spindletop to Enron*, 24 J. LAND RESOURCES & ENVT'L L. 187 (2004).

251 Hardin, *supra* note 198.

252 *See supra* note 143 and accompanying text.

253 PILLING, *supra* note 160, at 149-50.

section. It is therefore necessary to determine whether the oversupply could otherwise be addressed in a different manner.

To say otherwise implies bringing new processes and actors to bear on the problem of escaping the Malthusian trap. It thus requires a stock-taking of existing actors and processes under the environmental law paradigm to fully explain the value of the current direction. So far, climate governance in the environmental law paradigm has leaned on state actors. Specifically, international treaty structures such as the Paris Agreement focus on nations as the appropriate focus for action.[254]

Recent political events have pushed compliance with the Paris Agreement below the national level. Specifically, the election of President Trump in the U.S. has elevated sub-national governmental actors and brought their tools to bear on the climate issue.[255] States such as California and cities such as New York City have used their regulatory powers to assist in climate change efforts.[256] This development has added significant power and resilience to global climate governance and has amplified and transformed state-based climate governance by bringing new and different tools to the table to help in the common goal of climate defense. For example, U.S. state and local governments have used their zoning powers to address climate change in ways the federal government cannot because of the inherently local nature of land use law.[257]

At this stage, there remains an important set of processes and actors missing that could be leveraged in climate governance. As the work of Elinor Ostrom on polycentric commons governance has established, it is the combination of political, social, and market forces, rather than the exclusive use of one force over the others, that stands a chance to overcome endemic commons management problems.[258] Importantly, the inclusion of market forces and financial markets in climate governance has been limited. As a matter of commons management theory, this design feature of climate law is deeply problematic.

This is a significant design flaw for reasons more obvious than the intricacies of polycentric commons governance theory. First, actors that drive market forces have increasingly come to see climate change as a vital problem in which they wish to engage. Blue chip companies project

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[254] Paris Agreement, *supra* note 57.

[255] Frederic G. Sourgens, *States of Resistance*, 15 DUKE J. CONST. L. & PUBLIC POL'Y 91, 91-168 (2019).

[256] *Id.*

[257] Renee Cho, *How New York City is Preparing For Climate Change*, COLUMB. EARTH INST. (Apr. 26, 2019), https://blogs.ei.columbia.edu/2019/04/26/new-york-city-preparing-climate-change/.

[258] ELINOR OSTROM, GOVERNING THE COMMONS (2015); ELINOR OSTROM, UNDERSTANDING INSTITUTIONAL DIVERSITY (2009).

a $1 trillion loss due to climate change in the next five years and presumably would wish to find means to avoid such losses.[259] At this point, it is telling that even car manufacturers are pleading with the Trump administration for higher emissions standards.[260] Oil companies are jumping into renewable energy projects.[261] And companies like Starbucks are entering into agreements to offset their use of "dirty" electricity through offset purchases of clean energy generated elsewhere.[262]

Yet, current governance structures do not permit these market forces to join governance processes as full participants. It thus loses out on two powers of markets. First, they leverage capital to test ideas that can be brought to bear to solve pressing problems in the expectation of future reasonable returns on investment. Importantly, like the pharmaceutical industry shows, this structure is able to absorb the significant development costs for failed ideas—for example, drugs that never make it to market.[263] Second, markets involve important and unique ways to communicate and understand information throughout social processes. They set prices on the basis of what can reasonably be supplied and thus provides a counterweight for social processes complaining about the cost of current mitigation strategies.

A market-based engineering solution can bring these advantages to bear by looking for a means to produce enough $CO_2$-equivalent GHGs to return to a sustainable climate balance. The Paris Agreement and the IPCC currently suggest that this balance is achieved when temperatures can be held to close to 1.5°C above pre-industrial levels.[264] This means that the engineering/energy law solution is to find a mechanism that would be able to sustainably remove $CO_2$ from the atmosphere.

[259] *World's Biggest Firms Foresee $1 Trillion Climate Cost Hit*, N.Y. TIMES (June 4, 2019), https://www.nytimes.com/reuters/2019/06/04/business/04reuters-climate-change-companies-disclosure.html?searchResultPosition=1.

[260] Coral Davenport, *Automakers Tell Trump His Pollution Rules Could Mean 'Untenable' Instability and Lower Profits*, N.Y. TIMES (June 6, 2019), https://www.nytimes.com/2019/06/06/climate/trump-auto-emissions-rollback-letter.html?searchResultPosition=3.

[261] *See* note 119.

[262] Emma Foehringer Merchant, *Starbucks Buys Aggregated Wind and Solar Portfolio With Help From LevelTen*, GREEN TECH MEDIA (June 5, 2019), https://www.greentechmedia.com/articles/read/starbucks-buys-aggregated-wind-and-solar-portfolio-with-help-from-levelten#gs.hb6rhs.

[263] Matthew Herper, *The Cost Of Developing Drugs Is Insane. That Paper That Says Otherwise Is Insanely Bad*, FORBES (Oct. 16, 2017), https://www.forbes.com/sites/matthewherper/2017/10/16/the-cost-of-developing-drugs-is-insane-a-paper-that-argued-otherwise-was-insanely-bad/#557ed39f2d45.

[264] Paris Agreement, *supra* note 57, at art. 2(2); IPCC, *supra* note 4, at 56.

Energy law is premised on the notion of a regulated market.[265] As such, an energy paradigm would charge on the basis of generation and use rather than on the basis of pollution.[266] Rudimentarily, rates in this market would be set after public consultation with all stakeholders and with the approval of a regulator.[267] Further, regulators would be able to defray some costs for those affected by these rates by providing subsidies and thus paying for certain kinds of energy generation with public funds.[268] This market would mimic many features of Ostrom's successful commons. Ostrom's commons management solutions all point to a communal internalization of the externalities and costs of management.[269] It then shares the burden of management and upkeep roughly according to benefits received from the commons.[270] However, it supplements this burden with the opportunity for political and community actors to shoulder the difference between the total cost of management and upkeep on the one hand and the management obligations undertaken by the commons participants on the other.[271]

This approach has two significant advantages over a polluter pays approach. First, the energy model is consistent with the principle of differentiation discussed above in a way that the polluter pays principle is not. The energy model looks for the ultimate users of the service to determine who should participate in commons management (or pay utility rates). The users are end users, and those end users are overwhelmingly located in North America or Western Europe, not in Indonesia or the Philippines.[272] In other words, rather than looking for smokestacks located in Indonesia or the Philippines,[273] this approach would look at companies such as Nike, Adidas, Under Armour, Target, Monoprix, and Marks & Spencer to support carbon removal efforts.

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265 *Id.*

266 Ravi Soopramanien, *The WTO Agreements and the Regulation of Energy Markets: Is There A Good Fit?*, 34 PACE ENVTL. L. REV. 87, 91-94 (2016).

267 *Understanding How Rates Are Set*, PG&E (2019), https://www.pge.com/en_US/small-medium-business/your-account/rates-and-rate-options/learn-how-rates-are-set/learn-how-rates-are-set.page.

268 Bill Maloney et al., *Renewable Energy Subsidies, Yes or No?*, FORBES (Mar. 23, 2019), https://www.forbes.com/sites/uhenergy/2018/03/23/renewable-energy-subsidies-yes-or-no/#51f17636e232.

269 OSTROM, GOVERNING THE COMMONS, *supra* note 258, at 8-102.

270 *Id.*

271 *Id.*

272 *See* U.N. Conference on Trade and Development, *Global Supply Chains: Trade and Economic Policies for Developing Countries* (2013) (available at https://unctad.org/en/PublicationsLibrary/itcdtab56_en.pdf).

273 SANDS & PEEL, *supra* note 125, at 242-44.

Second, it assumes that many of the costs in question should in fact be borne by the community as a whole.[274] It allows that energy usage is not produced by a pure market, but rather one in which (even heavy) subsidies are appropriate.[275] It thus allows one to move away from an indirect model of taxation that attaches to an activity such as a carbon tax. It is instead possible to consider distributing the costs of carbon removal across society as a whole through the normal budget process. This provides significantly more flexibility to policymakers because it allows them to raise revenue through the full gamut of tax policy tools. To put this in the context of U.S. taxation, this model would mean that if the federal government paid for carbon removal in the first instance through "ordinary" taxation, the poorest third of the U.S. population would not be asked to contribute to the cost of carbon removal.[276]

An energy-based design thus would extend the benefit of carried development costs from energy generation to GHG mitigation. As will be discussed below, this is a significant advance because it frees up market resources needed to overcome the apathy gap discussed in the last section while leaving governmental resources available for further mitigation.

### *C. The Compatibility of Energy and Environmental Paradigms*

One should not misinterpret the need to use an energy law paradigm in addressing climate change to mean that an environmental law paradigm is irrelevant. Rather, the point is that the legal tools available to policymakers extend beyond those made available by international environmental law. These tools are additional to and complementary of the environmental law efforts that have already been made.

Leading theorists argue that suggestions such as those outlined in this Article suffer from moral corruption by avoiding the clear duty to reduce $CO_2$ emissions.[277] They argue that any approach that relies on geoengineering introduces the moral hazard of encouraging new and additional $CO_2$ emissions.[278] They further submit that because we enjoy the benefits of emissions today and pass the cost of failing to mitigate onto future generations, the tragedy of the commons analysis will not lead to a satisfactory result because the commons will not collapse fast enough

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[274] OSTROM, GOVERNING THE COMMONS, *supra* note 258, at 14-15.

[275] Maloney, *supra* note 222.

[276] Quentin Fotrell, *More than 44% of Americans Pay No Federal Income Tax*, MARKETWATCH (Feb. 26, 2019), https://www.marketwatch.com/story/81-million-americans-wont-pay-any-federal-income-taxes-this-year-heres-why-2018-04-16.

[277] GARDINER, *supra* note 40, at 301-38; HAMILTON, *supra* note 49, at 162-66.

[278] GARDINER, *supra* note 40, at 301-38; HAMILTON, *supra* note 49, at 166-73.

to impact today's decision-making on commons conservation.[279] Finally, these theorists submit that the costs of mitigation will be lower than the costs of removal and that the energy paradigm is therefore straightforwardly irrational.[280] Any submission, if successful, would suggest that the environmental law paradigm is the only solution and that current apathy suggests an institutional failure of global and domestic governance at a catastrophic level.

A full reply to these concerns is beyond the scope of this Article, but outlining a defense for coexistence between the energy and environmental law paradigms is certainly warranted. Beginning with the pragmatic rejoinders, it is clear that at this point a pure environmental solution to climate change does not stand a reasonable chance to avoid climate tipping events.[281] The window of action is vanishingly short.[282] Political will appears insufficient to rise to the moment in that window.[283] No matter the philosophical merits of the ethical critique of an energy paradigm, at this time the preferred policy initiative, pure mitigation, appears hopelessly unrealistic for the reasons outlined above.

Further, while it may theoretically be true that past generations did not encounter climate change as a tragedy of the commons problem, the current one does. As a matter of reality, today's "median human" will be 40 years old when tipping events are predicted to have a moderate-to-high likelihood of starting to occur.[284] Even assuming that projections are too pessimistic and tipping events happen another ten years later, today's "median human" will be alive to see these events and suffer the consequences.

The theoretical answer suggests that every rational actor would prefer to avoid the tragedy of the commons. Were this not the case, the tragedy of the commons would not be a "tragedy" at all. In this context, rationality is defined by a person's ability recognize that the overuse of a commons leading to its inevitable collapse is a catastrophe to be avoided. This means that there must be a theoretical explanation for conditions in which rational actors nevertheless bring about the collapse of a commons such as the global climate.

Communicative rationality may explain this conundrum. Communicative rationality suggests that communication is rational to the

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[279] GARDINER, *supra* note 40, at 143-84.
[280] *See id.* at 270-97 (discussing the imprudence of using discount rates for future harm in climate related cost-benefit analysis).
[281] *See* section II.A.
[282] IPCC, *supra* note 4, at 56.
[283] *See* section II.A.
[284] *See* section I.A.

extent that it makes (morally) intelligible claims to at least one member of the relevant group.[285] It is morally intelligible to make two relevant submissions.

First, it is rational for me to submit that I will participate in conduct that will lead to the collapse of a commons if I see everyone else doing so. In that instance, it is rational for me to submit that my playing the hero is precisely *ir*rational as it does not suffice to save the commons. A response to this problem that uses the environmental paradigm alone is less optimal than a response that employs a combination of the environmental and energy paradigms. The environmental paradigm so far has not brought about a solution that actually promises to save the climate commons, and it asks for significant sacrifices to be made to fall short of the goal. The energy paradigm aids the environmental paradigm in creating a workable solution. This is because a combination of both paradigms has significantly greater rational purchase power and moves the burden of production on the party seeking to defect in a way that the environmental paradigm alone does not.

Second, it is similarly rational for me to submit that I should not be made disproportionately worse off by the maintenance of the commons compared to others, particularly if I am already comparatively disadvantaged by prior socioeconomic conditions. "Unless we all suffer fairly as a result of commons management, I suffer enough already as is," is a rational statement in that it is certainly morally intelligible. Importantly, climate policy has not maximally protected those most vulnerable to the effects of climate policy *itself*.[286] It is therefore rational, all things considered, for those vulnerable persons to object to climate policies as they have done in Australia and continue to do in France and in the U.S. These policies have harmed these vulnerable communities and have thus allowed affected persons to appeal to the negative duties of policymakers to do no harm.[287] Defection is therefore rational for this second reason as far as it goes.[288] But again, this claim to rationality is significantly lessened when the energy paradigm is added to the mix. There is now no less restrictive climate policy available that has a chance of averting catastrophic harm to all (including the vulnerable group).

[285] 1 JÜRGEN HABERMAS, THE THEORY OF COMMUNICATIVE ACTION 11 (Thomas McCarthy trans., 1984) ("[a]n assertion can be called rational only if the speaker satisfies the conditions necessary to achieve the illocutionary goal of reaching an understanding about something in the world with at least one other participant in communication.")

[286] *See* section II.A.

[287] See GARDINER, *supra* note 46, at 153 ("in particular, many people believe that violations of negative duties not to harm are much more serious, from a moral point of view, than violations of positive duties to aid.")

[288] *See* PILLING, *supra* note 206, at 91-93.

Unlike under the environmental paradigm alone, this increases the burden of production significantly for any person rationally wishing to defect.

Finally, the arguments as to overall costs miss an important point about path dependence and its role in development. As the discussion below will show, it is without a doubt true that carbon removal is significantly more expensive than mitigation. The direct cost to taxpayers of a Green New Deal premised on mitigation will almost certainly be less than the direct cost to taxpayers under a Green New Deal premised on removal. If the objection to climate ambition is the cost of a potential solution, is it not just as likely that removal costs will lead people to balk even more than with mitigation costs?

To begin with the punchline, *Geo-Markets* disagrees with this cost analysis because it looks only to immediate costs of both programs and does not consider the distribution of the indirect cost of a fast infrastructure swap. Carbon removal allows people dependent on existing energy infrastructure to continue to make a living while adapting to the gradual structural change involved in the swap. And the affected parties include more than executives in oil companies. They include union workers in the two leading unionized private-sector industries (utilities and transportation),[289] farmers who relied on existing government programs to purchase expensive equipment,[290] ranchers and ranch hands raising cattle,[291] and hospitality workers dependent upon tourism.[292] In short, the parties that would be affected by an energy infrastructure swap include a broad cross section of the electorate that recently showed its muscle against effective mitigation policies in countries such as the U.S. and Australia.

An infrastructure swap may well threaten the livelihood of these very people. Such a swap is an exercise in creative destruction: it will destroy industries, it will put people out of work, and it will increase costs of production in the short term in a manner that will deeply disrupt energy-intensive businesses as well as businesses with narrow profit margins.[293] If the infrastructure swap proceeds too quickly the results would be

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[289] Union Member Summary, U.S. Bureau of Labor Statistic (Jan. 18, 2019), https://www.bls.gov/news.release/union2.nr0.htm.

[290] Polly Botsford, *Climate Justice: French 'Gilets Jaunes' Protests Provide Lessons for Countries Transitioning to Low-Carbon Economies*, INT'L BAR ASSOC. (Jan. 25, 2019), https://www.ibanet.org/Article/NewDetail.aspx?ArticleUid=81C900E0-0804-41B6-9BA5-A96C485D4BD5.

[291] Aaron E. Carroll, *The Real Problem with Beef*, N.Y. TIMES (Oct. 1, 2019), https://www.nytimes.com/2019/10/01/upshot/beef-health-climate-impact.html.

[292] Andy Newman, *If Seeing the World Helps Ruin It, Should We Stay Home?*, N.Y. TIMES (June 3, 2019), https://www.nytimes.com/2019/06/03/travel/traveling-climate-change.html.

[293] Ricardo J. Caballero, *Creative Destruction*, MIT, available at https://economics.mit.edu/files/1785.

catastrophic. It is akin to economic shock therapy—a prescription that failed spectacularly when implemented by free-market pioneers in the former Soviet bloc after the fall of the Soviet Union,[294] and failed even more tragically when implemented by Stalinist zeal in the same territory some sixty years earlier.[295] Carbon removal is more expensive but less abrupt, and this would give social and economic systems more time to adapt to a swap. It is therefore more likely, all things considered, to be successful.

The technical reason for this submission is path dependence. Path dependence implies that economies will achieve suboptimal or comparatively inefficient outcomes because of the cumulative effect of past choices.[296] Assuming that every person in a society learned to type on a QWERTY keyboard, it would be difficult to switch to a different constellation of keys because of the reliance interests invested in the past technology.[297] While a different energy configuration would achieve climate change goals more cheaply, the swap runs into the QWERTY problem because social systems have significant and systemic reliance interests in the carbon economy.[298] These reliance interests must be borne in mind in designing institutions.

Path dependence is a symptom of the fact that humans, as well as natural ecosystems, are unable to adapt to radical and fast changes in environmental conditions. If conditions are changed more gradually, the results in both the social and ecological settings are astounding—a radical evolutionary reorganization that can create new path dependencies.[299] The approach of running environmental and energy paradigms in parallel relies on this understanding of evolutionary path dependence and hopes to enlist it to prepare the groundwork for the inevitable evolutionary changes in social systems that our future (and not just our energy future) must hold.

## III. THE CARBON REMOVAL GEO-MARKET

Carbon removal is imperative for two reasons. First, carbon removal is needed to achieve our GHG mitigation goals—it is simply not possible to reach those targets without also employing carbon removal

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[294] MORRIS ROSSABI, MODERN MONGOLIA: FROM KHANS TO COMMISSARS TO CAPITALISTS 49-55 (2005).

[295] TIMOTHY SNYDER, BLOODLANDS, EUROPE BETWEEN HITLER AND STALIN 21-119 (2010).

[296] Oona Hathaway, *Path Dependence in the Law: The Course and Pattern of Legal Change in a Common Law System*, 86 IOWA L. REV. 100 (2001).

[297] *Id*. at 111.

[298] *Id*.

[299] *Id*. at 114-5.

technologies. The discussion in the last section shows as much. Second, carbon removal is needed to slow or stop climate change even if GHG emissions are reduced to zero through mitigation efforts alone. As discussed above, climate change occurs because of the absolute amount of GHGs in the atmosphere.[300] To halt climate change therefore requires a stabilization of absolute amounts of GHGs.[301] As it stands, we are already experiencing the effects of climate change—to the point that a group of the world's largest businesses estimate to lose approximately $1 trillion in the next five years alone.[302] These losses would remain permanent without carbon removal.

Experts refer to the first point—achieving GHG mitigation goals—when they say that "we must become carbon negative."[303] In order to maintain today's climate, we must remove tomorrow's carbon emissions from the atmosphere. To maintain yesterday's climate, we must remove today's carbon emissions. We can only do that if humans remove more GHGs than they emit. Whether from an environmental or an energy perspective, deploying carbon removal technologies as quickly as possible is essential. The best way to do so is to create a geo-engineering marketplace—or geo-market—for carbon removal.

### *A. Current Technology*

There is currently no clear-cut best technology for carbon removal. The most desirable technology today is direct air capture and storage of $CO_2$.[304] This approach uses a chemical reagent to interact with $CO_2$ or membranes which would physically trap $CO_2$.[305] This technology could theoretically remove all annual human $CO_2$ emissions,[306] but it is unclear how quickly it could be mobilized on a large scale.[307]

Other approaches have attempted to combine biomass fuels with carbon capture with limited success.[308] One of the main questions is whether this biomass approach could in fact be scaled to obtain sufficient

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300 HARVEY, *supra* note 48, at 7.

301 *Id.*

302 Brad Plumer, *Companies See Climate Change Hitting Their Bottom Lines in the Next Five Years*, N.Y. TIMES (June 4, 2019), https://www.nytimes.com/2019/06/04/climate/companies-climate-change-financial-impact.html.

303 *See* Arthur Neslen, *CO2 Emissions Must be Zero by 2070 to Prevent Climate Disaster, UN Says*, GUARDIAN (Nov. 19, 2014), https://www.theguardian.com/environment/2014/nov/19/co2-emissions-zero-by-2070-prevent-climate-disaster-un (discussing need to become carbon negative by 2050 according even to more optimistic 2014 projections).

304 Kintisch, *supra* note 11, at 42-44.

305 *Id.* at 42.

306 *Id.*

307 *Id.*

308 *Id.* at 45.

biomass.[309] Another biological approach to carbon capturing is biochar,[310] which relies upon a pyrolysis, a process in which organic material is burned in the absence of oxygen.[311] This approach has potential agricultural benefits in creating soil nutrients but also suffers from question of scalability given its small scale of current application.[312]

A further potentially popular technique is ocean iron fertilization.[313] Oceans are the currently are largest storers of $CO_2$.[314] Crudely, ocean fertilization seeks increase the growth of algae that could trap $CO_2$, sink to the floor of the ocean, and die.[315] This approach has significant unknown side-effects for the marine environment and could itself be globally disastrous for maritime bio-diversity; as a result, it is arguably internationally unlawful.[316]

Finally, another approach has been to theorize that it is possible to use enhanced weathering to trap $CO_2$.[317] This approach relies upon chemical reactions that happen when $CO_2$ reacts with water and forms bicarbonate ions.[318] These ions in turn create sediment that could be stored on the ocean floor.[319] This technique would seek to accelerate these processes.[320] It would have the beneficial side effect of reducing ocean acidification caused by increased atmospheric $CO_2$.[321] However, this approach remains in the very early experimental stages.[322]

The current state of technology means that all of these approaches still owe proof of concept. In such an environment, a market can allow, and benefit from, competition between the different approaches. However, this market must be sensitive to the fact that the promise of removing carbon from the atmosphere is something quite different from actual carbon removal in the promised quantities. The market mechanism therefore must be able to reward actual performance without running the risk of paying for sales pitches, which ultimately fail to deliver needed results.

309 *Id*.
310 Kintisch, *supra* note 11, at 48-49.
311 *Id*.
312 *Id*. at 49.
313 *Id*. at 47-8.
314 *Id*.
315 *Id*.
316 SANDS & PEEL, *supra* note 171, 937.
317 Kintisch, *supra* note 11, at 50-1.
318 *Id*.
319 *Id*.
320 *Id*.
321 *Id*.
322 *Id*.

### *B. Carbon Licenses*

It is both lucky and ironic that there is precedent for the production of a difficult-to-extract resource of then-difficult-to-ascertain commercial value: oil.[323] The traditional structure for the international exploration, development, and production of oil and gas reserves involves concessions or licenses.[324] These licenses permit energy companies to produce and market the oil and gas and provide fiscal terms pursuant to which production occurs.[325] International oil licenses (and domestic oil and gas leases) share certain key characteristics that can inform the design of geo-markets for carbon removal.

First, the working interest holder—the oil company producing oil and gas from the licensed property—pays the royalty owner—the owner of the oil and gas reserves in place—a bonus for the right to produce.[326] In the international context, the royalty owner is the state.[327] The model for the first geo-market tracks this license structure from the oil sector with some necessary adjustments. The key benefit of a license structure is that the royalty owner (the state, in this case) does not pay for the development of the resource.[328] The working interest owner (that is, the operator) carries the risk of exploration and development.[329] In fact, the working interest owner pays the royalty owner (the state) for the right to produce rather than the other way around.[330] In other words, the operator of a carbon removal project would pay the government for the right to operate at the front end. The end purchaser of produced $CO_2$ does not pay the operator until the operator has proved that its concept is working and is in fact producing $CO_2$.

Second, in the oil and gas context, the oil and gas company must make pre-defined efforts (drill a well, discover oil in commercial quantities) within a "primary term."[331] Once the company does so, it can then produce oil or gas for as long as the project supports production in paying quantities in the "secondary term."[332] A failure to continue production leads to the operator's forfeiture of all future rights to operate the

323 *See* DANIEL YERGIN, THE PRIZE, THE EPIC QUEST FOR OIL, MONEY AND POWER 19-164 (1990) (providing a historical account of the early days of oil exploration).
324 PETER CAMERON, INTERNATIONAL ENERGY INVESTMENT LAW 104-5 (2010).
325 *Id*.
326 *Id*. at 10; OWEN ANDERSON ET AL., OIL AND GAS LAW AND TAXATION 24-31 (2017).
327 CAMERON, supra note 324, at 10.
328 David E. Pierce, *Rethinking the Oil and Gas Lease*, 22 TULSA L.J. 445, 447 (1987).
329 *Id*.
330 ANDERSON ET AL., *supra* note 326, at 22-34.
331 ANDERSON ET AL., *supra* note 326, at 216-79.
332 *See* sources cited *supra* note 331.

license.[333] In the international context, states frequently impose specific, detailed work obligations on oil and gas companies during the primary term in order for those companies to keep their rights to produce under the license.[334] In a carbon removal geo-market, the government could similarly tailor the demands it makes to suit its needs before any purchaser of produced $CO_2$ (including the government) must pay. Most importantly, the government could insist that the operator of the carbon removal project remove a set amount of $CO_2$ in a fixed period (say 1,000 tons a day for a 30-day period) to declare that the operator has met commercial operations obligations or produced $CO_2$ in commercial quantities sufficient to trigger the license requirement of the production phase.[335] Alternatively, the government could simply require a certain production volume within the primary term to move the project into the secondary term.[336] To avoid unjust enrichment, the operator would then receive a lump sum payment for primary term production upon declaration of commercial operations as compensation for services rendered prior to commercial operations being declared. This would allow the government to require full proof of concept before paying.

Such an approach would leverage private capital to carry the risk of failure of a specific technology (and "carry" the government through production)—in the expectation of a significant reward to the extent that the technology is successful. If the government is the end purchaser of $CO_2$, this means that the licensing government incurs no costs until such time as a benchmark set by the government has been met. If the government passes on the obligation to purchase $CO_2$ to certain industries or end consumers, these industries or end consumers would not be burdened with an obligation to make payment until production is actually online.[337]

This structure shows promise in enticing financially capable investors. At this point, private investors such as Bill Gates have begun to explore

333 *Id.*

334 *See* Robert Attai, *Business & Operational Risks, Remedies and Defensive Tactics for Consortium Participants Faced with Pre-Discovery Default*, ROCKY MTN. MIN. L. FOUND. SPECIAL INST. Pt. 23, 2 (2015) ("The venture initially burns through cash to fund license acquisition costs and the Minimum Work Obligations set forth in the license.").

335 *See* Jessica E. McDonald & Zachary M. Wallen, *Defining "Production in Paying Quantities": A Survey of Habendum Clause Cases Throughout the United States*, 90 N.D. L. REV. 383 *passim* (2014) (discussing the requirement of production in paying quantities in oil and gas leases).

336 *See* Ernest Smith, *Typical World Petroleum Arrangements*, ROCKY MTN. MIN. L. FOUND. SPECIAL INST. CH. 9 (1991) (noting that "work obligations will normally be spelled out in detail" in licenses).

337 For such an arrangement in the airline industry, *see* BODANSKY ET AL., *supra* note 64, at 272.

investment in carbon removal.[338] Sir Richard Branson similarly is reported to have already invested in some relevant technology.[339] Researchers such as David Keith at Harvard have also taken significant steps toward development of the technology.[340] Once the international community—or at least a coalition of interested states—has developed a robust pricing mechanism, a market should develop quickly given existing investments in technology.

Third, in the international context, the working interest holder or operator then receives the right to explore, develop, and market the oil according to a set of carefully set out standards.[341] In the domestic context, the working interest holder must comply with implied covenants to protect the reservoir against drainage by operating as a prudent operator.[342] To the extent that the oil and gas company complies with these work obligations or acts as a prudent operator, it then is entitled to the revenue from its production, minus the payment of a royalty to the royalty owner.[343] If it does not comply with these obligations, it is liable for the damage it has caused.[344] These rights and covenants, too, are helpful in designing the carbon removal structure. The government can remain proactive in setting out obligations that a carbon removal company must meet. For instance, it could require that the operator meet certain environmental benchmarks in producing carbon. Payment again is conditional upon the operator meeting its work obligations.

In this context, too, the state could link its regulatory role and its role as a licensor or royalty owner. Carbon removal technologies can themselves be environmentally risky, as the discussion of ocean iron fertilization above has shown. The state should step in to prohibit or at the very least regulate means of carbon capture that pollute with unacceptable consequences in their own right.

The license structure gives states the ability to regulate what type of carbon removal technology is used by tying work obligations to

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338 John Vidal, *How Bill Gates Aims to Clean up the Planet*, GUARDIAN (Feb. 4, 2018), https://www.theguardian.com/environment/2018/feb/04/carbon-emissions-negative-emissions-technologies-capture-storage-bill-gates.

339 Andrew Czyzewski, *The down-to-earth side of geoengineering*, THE ENGINEER (July 15, 2011), https://www.theengineer.co.uk/the-down-to-earth-side-of-geoengineering/

340 Jeff Tollefson, *Sucking Carbon Dioxide from Air is Cheaper than Scientists Thought*, NATURE (June 7, 2018), https://www.nature.com/articles/d41586-018-05357-w.

341 Julian Cardenas Garcia, *The Era of Petroleum Mega Cases*, 35 HOUS. J. INT'L L. 537, 555-56 (2013).

342 Monika Ehrman, *One Oil and Gas Right to Rule Them All*, 55 HOUS. L. REV. 1063, 1074-75, 1102 (2018).

343 *See id.* at 1103.

344 *Id.*

meaningful environmental impact assessment requirements.[345] To the extent that regulators are uncertain about the potential negative environmental impacts of carbon removal, the work obligation provisions in a license give the regulator a means to control those impacts by withholding payment until the technology is sufficiently safe for deployment. The license structure thus provides the regulator with a significant *ex ante* tool to secure environmental compliance in addition to its traditional tool of *ex post* enforcement. This too creates significant design advantages for this emerging technological field.

The key benefits of a license structure should be readily apparent. The structure creates revenue in the early stages of a project for the government licensing it. It does not cost money to start. It only starts to cost money if tangible benefits, measured against benchmarks set at the outset, are realized. And the government can insist on the operator's stringent compliance with work obligations. The government, in other words, has a significant amount of control without shouldering a significant amount of the risk (financial and otherwise) of the carbon market.

### *C. Who Purchases?*

The environmental law paradigm discussion above has pointed out the dangers of passing on costs of $CO_2$ mitigation to emitters directly.[346] This suggests that the state should be the predominant end purchaser of emissions in a carbon removal market. Such a structure would allow the state to raise revenue for carbon removal through its general budget process instead of through indirect taxation mechanisms like a carbon tax. It also would permit the state to coordinate how contributions to carbon removal efforts would be structured.

Importantly, however, the state need not be the only purchaser of $CO_2$ in the removal geo-market. It simply needs to create the market infrastructure and carry the initial cost of creating the market for private parties to participate in this marketplace.[347] Consistent with a common pool resource management approach, private actors can then contribute directly in the effort to use the resource (in this case, $CO_2$ removal) in the most sustainable manner possible over the long term.[348] Existing efforts by industries like the global airline industry to self-impose obligations to

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345 *See* SANDS & PEEL, *supra* note 121, at 657-81.
346 *See* Section II.A.
347 OSTROM, GOVERNING THE COMMONS, *supra* note 258, at 133-42, 189.
348 *Id.* at 90, 189-90.

remediate for their emissions suggest that market actors would in fact participate in this manner once a market has been set up.[349]

Further, one of the ethical concerns in favor of mitigation efforts and carbon taxation has been to eliminate luxury emissions which pass undue burdens on to future generations.[350] Regulators may well be able to determine which industries truly qualify as industries responsible for luxury emissions and require that those industries purchase carbon removal credits for the emissions in question.

### *D. Pricing to Induce Investment*

Any astute observer will have discovered a snag in this structure. There is a robust market for oil.[351] But as of yet, there is no similar vibrant market for carbon removal.[352] There is no independent market for $CO_2$ today that would provide an economic incentive to produce it given current costs. The pricing structure therefore has to be set by the end users of the climate change mitigation: the global community. In other words, the license structure only works to the extent that the government guarantees payment of a certain amount over the life of the license in order to justify the initial investment.

#### *1. Setting the Original Price*

Energy markets have recently encountered a similar price setting problem in the solar energy context. European states in particular originally offered subsidized feed-in tariffs for electricity generated by new solar facilities. These feed-in tariffs were set for a fixed period of time and guaranteed a reasonable return on investment. These incentive structures were extraordinarily successful in bringing solar operators into the European market. In fact, they have made it possible for some European energy markets to contemplate the previously inconceivable: carry "base load" or basic energy demand in a marketplace with renewable energy. Financial incentives—government subsidies of a sort—work.

Prices should be set with the aim of attracting investment in the carbon removal industry. Some research suggests that the current price for

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349 BODANSKY ET AL., *supra* note 64, at 272.

350 *See generally* GARDINER, *supra* note 46, at 146-60 (explaining the moral problems related to passing environmental burdens on to future generations).

351 *See* Robert Rapier, *Why Oil Prices Have Crashed - And What Investors Should Do Now*, FORBES (June 7, 2019), https://www.forbes.com/sites/rrapier/2019/06/07/why-oil-prices-have-crashed-and-what-investors-should-do-now/#4c1820d55076.

352 For current market models, *see* BODANSKY ET AL., *supra* note 64, at 272.

carbon removal is $100 per ton.[353] Providing both for royalty and a reasonable profit margin, this would suggest an initial set price of $140 per ton. This would value total projected U.S. 2018 $CO_2$ emissions of 5.4 gigatons at $756 billion, or approximately 3.7% of U.S. GDP in 2018.[354]

At this point, it is not necessary to reduce $CO_2$ emissions to net zero immediately. Rather, IPCC projects that GHG emissions must be reduced by 45% from 2010 levels by 2030.[355] Although U.S. emissions were slightly higher in 2010 than in 2018, we can use 2018 emissions levels to calculate an approximate target amount for emissions reduction: 2.43 gigatons.[356] Taking into account projected reductions in GHG emissions through mitigation measures implemented by states and cities (17–24% reduction from 2005 emissions levels),[357] this leaves a net range of approximately 21–28% in additional reductions to be made up by removal as opposed to mitigation. Using 2018 emissions levels, this would mean that the U.S. would have to find a means to remove 1.134 to 1.51 gigatons per annum of $CO_2$ emissions. At the $140 per ton price, this would amount to a price of $158.76 billion to $211.4 billion.

Such a price would be economically sustainable. By comparison, the U.S. consumed approximately 7.5 billion barrels of petroleum in 2018.[358] At average oil prices of $64.94 per barrel for West Texas Intermediate, a rough approximation of the value of oil consumed in the U.S. in 2018, is $487.05 billion.[359] The additional $158.76–211.4 billion in carbon removal costs would thus amount, roughly, to the impact of a change in oil prices to $86.11–93.13 per barrel (or an increase in oil prices between $21.17–28.19 per barrel).[360] These prices are within the realm of recent

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353 *See* Tollefson, *supra* note 340.

354 *See* Pep Canadell et al., *Carbon Emissions Will Reach 37 billion tonnes in 2018, a Record High*, THE CONVERSATION (Dec. 6, 2018), http://theconversation.com/carbon-emissions-will-reach-37-billion-tonnes-in-2018-a-record-high-108041; *Gross Domestic Product, Fourth Quarter and Annual 2018 (Initial Estimate)*, BEA (Mar. 1, 2019), https://www.bea.gov/news/2019/initial-gross-domestic-product-4th-quarter-and-annual-2018.

355 IPPC, *supra* note 4, at 12.

356 Canadell, *supra* note 354.

357 *Country Summary, USA*, CLIMATE ACTION TRACKER (Nov. 29, 2018), https://climateactiontracker.org/countries/usa/. ("Recent analysis suggests that if recorded and quantified non-state and subnational targets were fully implemented, these measures could come within striking distance of the US Paris Agreement commitment, resulting in emissions that are 17–24% below 2005 levels in 2025 (incl. LULUCF).").

358 *Frequently Asked Questions: How Much Oil Is Consumed in the U.S.?*, U.S. ENERGY INFO. ADMIN. (last updated Sep. 4, 2019), https://www.eia.gov/tools/faqs/faq.php?id=33&t=6.

359 *See Average annual West Texas Intermediate (WTI) crude oil price from 1976 to 2019 (in U.S. dollars per barrel)*, STATISTA (last visited Feb. 15, 2020), https://www.statista.com/statistics/266659/west-texas-intermediate-oil-prices/.

360 *Id.*

memory of $147 per barrel of oil in 2008.[361] In other words, the cost of carbon removal for the United States, assuming current projections, would be well within past energy price environments so long as oil prices stay below $118.10 per barrel.[362] The pricing therefore seems to be economically sustainable, given that the economy has in fact absorbed even significantly higher and direct increases in energy prices in recent memory.

This price is also economically prudent. As the next section outlines, robust investment now will lead to a price drop in the future due to technological advances. The mechanism is known as technological forcing. Cass Sunstein was highly skeptical of such attempts at technological forcing in the context of the Kyoto Agreement.[363] Writing in 2005, he noted that a cost of $325 billion was not a prudent investment due to the economic contraction it would likely cause.[364]

But carbon removal is different for two reasons. First, Professor Sunstein's concern was that the Kyoto Protocol approach did not in fact force a technology that would be able to solve the climate problem.[365] It only concerned a reduction in flow in GHG emissions rather than a reduction in stock of GHGs in the atmosphere.[366] Carbon removal technology, unlike the Kyoto approach, would address this problem head on. Carbon removal is a paradigm-shifting tool precisely because it can reduce total levels of $CO_2$. Setting a price for carbon removal now thus forces a technology that actually *can* "'reduce' global warming directly."[367] Second, one can fairly surmise that the geo-market approach will not lead to an economic contraction of the kind Professor Sunstein anticipated in the context of a forced mitigation approach. Energy is a driver of economic activity. Reducing the amount of energy that is reasonably available—as would have been the case in Professor Sunstein's 2005 mitigation model—would have a negative impact on the economy.[368] Carbon removal does not have this impact precisely because it does not function like the carbon tax mechanism addressed by Sunstein.[369] Carbon taxation is felt directly by households and businesses

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361 Rebekah Kebede, *Oil hits record above $147*, REUTERS (July 10, 2008), https://www.reuters.com/article/us-markets-oil/oil-hits-record-above-147-idUST14048520080711.

362 *Id.*

363 SUNSTEIN, *supra* note 26, at 171-74.

364 *Id.* at 171, 173.

365 *Id.* at 172 ("[E]ven dramatic reductions in current emissions will only slow the rate of increase; it will not reduce global warming.").

366 *Id.*

367 *Id.*

368 *Id.* at 173.

369 SUNSTEIN, *supra* note 26, at 173.

that crucially depend upon the current energy infrastructure. The costs of carbon removal are not distributed in this way but rather borne in the same way as, say, the military budget. Carbon removal thus will promote economic activity (commercial carbon removal, lending related to carbon removal, and other services associated with carbon removal) rather than throttling economic activity (energy supply reduction by directly increasing the price of energy). As a result, it is more likely to lead to economic growth than economic contraction.[370] Paying the price of carbon removal, staggering as it might at first appear, is arguably economically prudent.

### 2. *Sun-Setting into a Market Price*

If the model is successful, an actual market price will arise independently of the original subsidized price for carbon development. Placing operators in competition with each other when bidding out licenses can encourage such a market to develop. The bidding process should consider at least two factors. First, the government should consider the size of the bonus that an operator would be willing to pay to develop and produce a carbon project. Second, the government should consider the price charged per ton.[371] The higher the bonus and the lower the price, the more attractive the project.[372] As bidders compete for projects, a market price will develop simply by pushing operators to propose lower and lower prices to ensure their selection.

Setting a sunset provision into the first generation of licenses will help create a robust and self-sustaining carbon market by preventing first movers from continuing production using inefficient methods or to achieving windfall profits for an undue period of time.[373] Again, this is not a problem that is beyond the scope of existing international energy law. Many international petroleum contracts provide for stabilization clauses to adapt the contract to changing market conditions.[374] These mechanisms could be employed in order to sunset particularly favorable early pricing once more efficient technologies have become readily available.

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370 *See* PILLING, *supra* note 206, at 228-29 (noting that money spent on pollution abatement is calculated as economic growth).

371 *See* Stephen Hood, *Obtaining Financing for Oil and Gas Projects in Latin America*, Rocky Mtn. Min. L. Found. Special Inst. Ch. 18 (2001) (discussing competitive bids for oil and gas projects in Peru).

372 *Id.*

373 CAMERON, *supra* note 324, at 8-13 (discussing windfall).

374 *Id.* at 59-94 (discussing such mechanisms in energy contracts).

Such stabilization or sunset provisions should still provide a sufficient incentive to invest by providing a reasonable return on investment.[375] Governments should look at the risk incurred by the operator to develop and operate the original project and then consider the cost of development to determine a reasonable payment to which the operator would be entitled.[376] Once this reasonable return on investment is achieved, however, the license holder should only be able to receive market prices for carbon that has been removed.

### *E. The "Bonus" Bonus*

A core benefit for the state of adopting such a license structure analogous to that in the oil and gas world is that the person wishing to obtain a license must pay to receive it.[377] As outlined above, the main mechanism in the oil and gas industry to structure such a payment is known as a "bonus."[378] Companies pay the bonus because they expect that they will earn more than the bonus by exploring, developing, and exploiting the leased area.[379]

Carbon removal presents different but analogous risks and rewards. Unlike with oil and gas, there is no risk that an operator will drill a dry hole—it will certainly be able to find $CO_2$ to remove.[380] The risk is rather that an operator will not be able to remove this $CO_2$ at a price point that would be commercially viable given the pricing environment. This risk structure is one that remains reasonably analogous to the oil and gas setting in which a bonus is paid on a regular basis.

If the amount of potential revenue is set at an attractive price, this bonus should be attractive even considering the risks involved. The pricing structure outlined in section III.B above should accomplish this. First, this pricing structure is premised upon current day, non-scaled prices and thus should already permit companies to make significant profits through economies of scale using existing technology.[381] Current technology is unlikely to permit companies to compete with each other on pricing in a meaningful manner—such competition would require

375 RREEF Infrastructure (GP) v. Spain, Case No. ARB/13/30, Decision on Responsibility and the Principles of Quantum, International Centre for Settlement of Investment Disputes (ICSID) Arbitration Trib., ¶ 517 (2018). *But see* 9Ren Holding S.A.R.L. v. Spain, Case No. ARB/15/15, Award, ICSID Trib., ¶ 309 (2019).

376 RREEF Infrastructure (GP) v. Spain, Case No. ARB/13/30, Decision on Responsibility and the Principles of Quantum, ICSID Trib., ¶ 524 (2018).

377 ANDERSON ET AL., *supra* note 326, at 22-34.

378 *Id.*

379 *Id.*

380 *Id.*

381 *See* Tollefson, *supra* note 340.

further technological advances that should occur once a market has been created.[382] Any competitive bidding to access the carbon removal geo-market therefore will rely upon the size of the bonus payment parties are willing to make.

Second, the pricing structure above also permits bonus bidding once carbon removal technology has matured. At that stage, companies will be able to look at established, less technologically and commercially risky revenue streams when deciding to bid on a project because they will have examples of profitable projects on which to base their own projections. This again should drive up bonus payments at the front end.

Why will companies compete? The key assumption of bonus payments is that states will only make available a limited number of carbon removal licenses. States will have to do so for fiscal reasons—they must be able to anticipate the payments to be made to carbon producers under existing licenses and raise revenue accordingly. Thus, although there is a very high supply of carbon, access to the highly lucrative carbon removal market would remain very limited. This in turn will create the competitive pressure to bonus bid, resembling bonus bidding incentives in the utilities context or oil and gas industry.[383]

As a matter of design, it would be desirable for recipients to use the money raised through bonuses to support climate change adaptation and climate change mitigation efforts. This could introduce a new and previously untapped source of short-term funding for climate change strategies right when that money is needed the most—the period of transition towards a climate safe energy paradigm. The bonus funds should therefore not be made available as general revenue. Rather, a well-designed carbon removal geo-market would require that bonuses paid for removal licenses be re-invested. Such a requirement could be anchored in the existing Paris Agreement structure. As outlined above, the Paris Agreement already anticipates and builds upon climate finance mechanisms.[384] Governments could take advantage of these mechanisms by requiring that bonus payments be made pursuant to Paris Agreement mechanisms and then earmarked by relevant institutions for use in the license state pursuant to the Paris Agreement project specifications.[385]

Such an anchor would provide a positive feedback loop between removal and the kinds of previously discussed adaptation and mitigation measures that may unify the energy and environmental paradigms. The

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382 *See* SUNSTEIN, *supra* note 26, at 174 (discussing the mechanism of technology forcing).

383 Thomas W. Hazlett, *Private Monopoly and the Public Interest: An Economic Analysis of the Cable Television Franchise*, 134 U. PA. L. REV. 1335, 1363-64 (1986).

384 ZAHAR, *supra* note 66, at 86.

385 *See id.*

carbon removal geo-market would provide a means to raise money in the short term (rather than spend it) in order to support needed heavy expenditures. It thus supports the Paris Agreement structure rather than competing against it.

### *F. Conclusion—Designing an Efficient Market*

Carbon removal licenses provide a potential means to give climate change mitigation and adaptation efforts a shot in the arm. States can use these licenses to leverage the financial capabilities of the marketplace to develop the best carbon removal technologies. By raising short term revenue through license purchases, states can finance other climate change mitigation and adaptation projects while delaying their payment obligations until pre-agreed carbon removal targets have actually been met by carbon removal operators. Finally, states can regulate and control carbon removal technology in a transparent fashion by issuing carbon removal licenses.

But to encourage an efficient market that relies upon the best technology, carbon removal licenses must be freely tradable.[386] If licenses are freely tradable, new operators with better technology can buy out first-generation license holders with older technology by paying a lump sum.[387] Since newer operators can generate a profit at a cheaper production price, a market should develop to incentivize such transactions. States will also benefit from accelerating markets for carbon removal by subsidizing new technology with old licenses (that is, allowing the trading of early licenses will make the higher prices available to first movers accessible to later innovators).

Efficient carbon removal markets have further advantages. Once anyone may purchase a license at a set price, states could step in and pick up excess capacity from existing projects or license their own projects even if the federal government were to cut back on its program to purchase carbon.[388] And in theory, there is nothing to prevent civil society from purchasing carbon directly from producers without the government (assuming that a regulatory structure for the carbon market exists).[389] Creating an efficient carbon removal market thus supports the current

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386 *Cf.* Howard R. Williams, *Conservation of Oil and Gas*, 65 HARV. L. REV. 1155, 1163 (1952).

387 *See* Cardenas, *supra* note 341, at 564-65 (discussing international farmout agreements in the oil and gas industry).

388 *See* Frederic G. Sourgens, *States of Resistance*, 15 DUKE J. CONST. L. & PUB. POL'Y 1 (2019) (discussing the efforts of California to defy the Trump administration's exit from the Paris Agreement).

389 *Cf.* Emma Foehringer Merchant, *Starbucks Buys Aggregated Wind and Solar Portfolio With Help From LevelTen*, GREEN TECH MEDIA (June 5, 2019).

trend in climate change efforts to create a more democratic, polycentric means of climate governance rather than relying exclusively on states and multilateral treaties.

Efficient carbon removal markets also allow payouts to particularly large GHG emitters for avoided emissions. Taking a cue from the "keep it in the ground" movement in the oil and gas industry, market designers could measure the economic cost of continuing to operate facilities emitting significant GHGs and then negotiate a reasonable price to halt existing emissions and replace the underlying facility or process with GHG neutral technology, considering future regulatory burdens and market environments.[390] In other words, efficient carbon removal markets will enable regulators and private actors alike to price whether current economic activity is worth maintaining or replacing with "greener" technological approaches in a pragmatic manner.[391] It also can do so far more readily than current environmental regulation can achieve on its own.

## IV. THE SOLAR RADIATION MANAGEMENT GEO-MARKET

### *A. The Edge of Knife*

Social systems and ecosystems share a common characteristic: they are highly sensitive to fast-acting change. Ecosystems can only adapt at a certain pace.[392] Within this pace, ecosystems prove highly resilient.[393] Move beyond this pace, however, and ecosystems start to die.[394] Social systems follow a similar pattern.[395] Social systems can change gradually in radical ways.[396] The faster the change, however, the greater the risk that the social system completely fails.

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390 For example, a coal plant could not expect to be paid the full price of carbon removal for its decision not to emit given that its decision not to generate might well have to do with other economic and regulatory factors. For a discussion of the "keep it in the ground" movement, *see* Monika U. Ehrman, *A Call for Energy Realism: When Immanuel Kant Met the Keep It in the Ground Movement*, 2019 UTAH L. REV. 435, 440 (2019).

391 *Id.* at 459-69.

392 *See* HAMILTON, *supra* note 55, at 67, 71.

393 *Id.*

394 *Id.*

395 *See* Brian Fath et al., *Navigating the Adaptive Cycle: An Approach to Managing the Resilience of Social Systems*, ECOLOGY & SOC'Y 24 (2015) (discussing the threat of collapse to social systems); Hathaway, *supra* note 296 (discussing the importance of path dependence for legal development). When path dependence is not a viable option, there is a heightened risk that resilience strategies of social systems will fail and lead to collapse of the social system.

396 Hathaway, *supra* note 296, at 114-15.

Climate change at this point requires fast acting change. The IPCC has warned that tipping elements might be reached in 2030.[397] If warming is not stopped by then, ecosystems will not recover.[398]

As it stands, the short window of action forecast by climate scientists may well be too short for meaningful action to have the desired effect. Swapping an entire energy infrastructure in a matter of a decade is unrealistic.[399] Any fast-acting change would cause massive social disruption that would likely bring climate action to a halt at just the wrong moment. Examples of such disruptions already exist, as shown in France with the Yellow Vest movement and in the United States in the form of the Trump administration.[400] But building a carbon removal infrastructure capable of reducing emissions sufficiently to stabilize the climate in that window is also unrealistic. Although the technology is within our grasp, it is unlikely that it will reach full deployment and reduce emissions in amounts necessary to balance the climate in just a decade. Thus, we must play for time so that we can complete climate change mitigation and adaptation at a politically and technologically achievable pace without triggering the tipping elements projected by IPCC.[401]

Solar radiation management is a technological development that can stall the clock.[402] It can cool the planet almost instantly,[403] and we are technologically capable of deploying it.[404] Because science suggests that the current timeline for climate action is too short, we face a choice: risk suffering through the tipping elements, or deploy solar radiation management.

Given the current state of science, politics, and engineering solutions, deploying solar radiation management is nearly inevitable. One of the strongest critics of solar radiation management appears to agree with this conclusion when he notes that the "only justification for deploying geoengineering is to make it easier politically to transform our economies and societies so that we live in a way that does not disrupt Earth's natural cycles and the processes that have allowed life to flourish."[405] Because solar radiation management seems unavoidable, this Article does not develop a justification for using solar radiation management but instead explains how to integrate solar radiation management as safely as

397 IPCC, *supra* note 4, at 56.
398 *Id.*
399 *See* Section I.D.
400 Mufson & McAuley, *supra* note 218.
401 *Id.*
402 DAVID KEITH, A CASE FOR CLIMATE ENGINEERING 90-91 (2013).
403 *Id.*
404 *Id.* at 96-97.
405 HAMILTON, *supra* note 55, at 208-09.

possible into the policy arsenal while addressing the predominant critiques of deployment.

For the reasons set out below, solar radiation management at this point remains a curse more than a panacea. Our current technologies are deeply ecologically destructive. The literature therefore calls for the use of solar radiation management as a matter of last resort and only when well regulated.[406] But as the moment of last resort is close at hand, we must explore how to deploy the technology; the question of whether to deploy it is already in the rear-view mirror. The remainder of this Article first explores the three main problems with solar radiation management and then sets out a market solution that integrates the technology into the broader market approach developed so far.

## *B. Three Problems*

### *1. The "Hell Broth" Problem*

The current dominant approach to solar radiation management proposes a solution that should strike any sane person as problematic: aerosolize up to four millions of tons of sulfuric acid per year into the stratosphere to offset global warming.[407] The sulfuric acid aerosol particles would reflect solar radiation back out into space before it enters the atmosphere, thereby preventing the radiation from warming the planet.[408] Sulfuric acid therefore acts as a shield to block the intake of energy from the sun.

The first benefit of this solution is that it replicates natural processes that have been widely studied by climate scientists: massive volcanic eruptions.[409] Because of this natural analogue, we can predict the costs of this kind of intervention in nature with a reasonable level of certainty.[410] It therefore presents fewer unknowns than untested technological approaches that may have unanticipated and lethal side effects on a planetary scale.[411] As distasteful as sulfuric acid may sound, it currently beats the alternatives.[412]

The second benefit is cost. It is well within our current engineering capacity to deploy sulfuric acid aerosol in sufficient quantities to slow climate change. The cost of this method has been estimated at several

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406 *See id.*; GARDINER, *supra* note 46, at 396.
407 KEITH, *supra* note 402, at 90-91.
408 KINTISCH, *supra* note 11, at 29-32.
409 WILLIAM SHAKESPEARE, MACBETH act 4, sc. 1; KEITH, *supra* note 402, at 90-94.
410 KEITH, *supra* note 402, at 90-94.
411 *Id.*
412 *Id.*

billion dollars annually.[413] To put this in perspective, to slow climate change would cost about the same amount as the annual revenue of the National Football League.[414] It is thus a figure that is far from astronomical and easy to generate.

Despite these advantages, it is easy to be skeptical. The use of large-scale sulfuric acid deployment will come at an enormous environmental and human cost. First, it will disrupt the climate chemistry that creates and maintains the ozone layer.[415] A prolonged deployment therefore would require us to recreate a climate problem we had largely solved through a set of multilateral treaties to protect the ozone layer.[416] Second, sulfuric acid will cause lethal air pollution that is likely to kill both people and animals (albeit fewer people and animals than would die if climate change were to proceed unchecked).[417] Third, sulfuric acid in the stratosphere returns to earth as acid rain, which will further destroy ecosystems and manmade structures alike.[418] To liken the method of slowing climate to a Shakespearean hell broth is thus not wide off the mark.[419]

To add to the nefarious impression, solar radiation management is a technology born from nuclear weapons testing.[420] To cope with the climate effects of nuclear winter, nuclear weapons testers designed solar radiation management technology to achieve less disruptive atmospheric cooling.[421] The technology's origins in nuclear weapons research remain a chilling reminder that the technology is potentially dangerous in light of the forces and scales involved.[422]

In sum, using currently available technology requires us to make tragic choices and take actions that we know will lead to fatalities and impact future generations—and those impacts would be the result of our affirmative choices rather than happenstance or inaction. Still, inaction is just as, if not more, fatal. One need not be an avid reader of Aeschylus to understand the gruesome overtones of this choice.[423]

The hell broth problem has legal consequences. The deployment of solar radiation management as it stands is likely to violate a number of

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413 *Id.* at 99-100.

414 Scott Soshnick & Eben Novy-Williams, *The NFL Nears $25 Billion Revenue Goal Ahead of Super Bowl*, CHI. TRIB. (Jan. 28, 2019).

415 KEITH, *supra* note 402, at 69-70; KINTISCH, *supra* note 11, at 32.

416 *See generally* BODANSKY ET AL., *supra* note 64, at 273-75.

417 KEITH, *supra* note 402, at 71.

418 HAMILTON, *supra* note 55, at 60.

419 WILLIAM SHAKESPEARE, MACBETH act. 4 sc. 1.

420 HAMILTON, *supra* note 55, at 120-21.

421 *Id.* at 120-29.

422 *Id.*

423 THE GREEK PLAYS: SIXTEEN PLAYS BY AESCHYLUS, SOPHOCLES, AND EURIPIDES (Mary Lefokwitz & James Romm eds. 2016).

international treaties. The likely effect on the ozone layer of solar radiation management triggers obligations under the Vienna Convention and its Montreal Protocol "to adopt policies to control, limit, reduce, or prevent these activities."[424] The deployment of solar radiation management would also trigger reporting obligations under the Convention on Long-Range Transboundary Air Pollution (CLRTAP).[425] Even the contemplated use of solar radiation management triggers procedural obligations to share information and permit affected publics an opportunity to participate under the Convention on Environmental Impact Assessment in a Transboundary Context, known as the Espoo Convention.[426] Finally, the Conference of the Parties under the UN Biodiversity Convention requires the exchange of information on geo-engineering.[427]

### 2. *The "Hotel California" Problem*

The use of solar radiation management also has a problem resembling a lyric from the Eagles song "Hotel California:"[428] it risks creating a situation in which "you can check out any time you like, but you can never leave."[429] Solar radiation management does not attack the cause of anthropogenic climate change—GHG emissions—but merely fiddles with the symptoms.[430] The technology not only does little to stop climate change, but in fact may create a situation in which it is impossible to wind down or terminate its use quickly if catastrophic side effects occur. In other words, we may become dependent on solar radiation management once we start using it.

What is worse, even if solar radiation management could be terminated, climate change would not pick up from the point at which solar radiation management was first used.[431] It would explode exponentially to where it would have been had it never been used in a matter of months.[432]

424 JESSE REYNOLDS, THE GOVERNANCE OF SOLAR GEOENGINEERING: MANAGING CLIMATE CHANGE IN THE ANTHROPOCENE 97 (2019) (citing to Article 2.2(b) of the Montreal Protocol). Reynolds submits that the effect on the ozone layer is too uncertain to draw a definitive conclusion that solar radiation management would substantially affect the ozone layer. REYNOLDS, *supra* note 13, at 71. David Keith, one of the leading researchers or solar radiation management and an advocate of its deployment, disagrees with that assessment. KEITH, *supra* note 402, at 69-70.

425 REYNOLDS, *supra* note 13, at 73.

426 *Id.* at 93-94.

427 *Id.* at 98-99.

428 THE EAGLES, *Hotel California*, *on* HOTEL CALIFORNIA (Asylum Records 1977).

429 *Id.*

430 KEITH, *supra* note 402, at 131-32; HAMILTON, *supra* note 55, at 65.

431 HAMILTON, *supra* note 55, at 70-71.

432 *Id.*

Ecosystems (and social systems) would not have any time to adapt to the rapid temperature change that would ensue if we turned off solar radiation management without also having tackled the underlying problem: billions of tons of GHGs accumulating in the atmosphere.[433] Such a sudden temperature change could lead to crop failures and pandemics.[434] Solar radiation management does not solve the underlying problem that brought about climate change.[435] It simply masks it.[436]

### *3. The Icarus Problem*

The third problem invokes the powerful cautionary tale of Icarus and reminds us that those flying too close to the sun out of overconfidence in their own engineering abilities tend to crash.[437] Critics of geo-engineering suggest that there are certain forces that are too godlike for humans to deploy.[438] Out of reverence for nature, humans should not try to manipulate the climate.[439] To do so would be hubris, and these critics argue that such hubris frequently has fatal consequences.[440]

In more prosaic terms, solar radiation is among the most the powerful natural forces that engineering has sought to harness. Solar radiation management tries to alter global phenomena caused by stellar activity.[441] The technology does this by mimicking and even scaling up some of the most powerful volcanic activity observed on earth.[442] And there is limited room for error when dealing with the atmosphere as a whole.[443] The worst-case scenario is a chain reaction that destroys the very condition for life on earth—a breathable atmosphere.[444]

The scientific achievements of the twentieth and early twenty-first century suggest that humans are up to the challenge.[445] Daunting as solar radiation and volcanic forces are, they are within the realm of other

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433 *Id.*
434 *Id.*
435 HAMILTON, *supra* note 55, at 65.
436 *Id.*
437 OVID, METAMORPHOSES 187-89 (Rolfe Humphries trans., 1955). Any plan relying on technology to escape from dangerous traps since the time of the Minoans therefore tend to lead to cautions of the potential for deadly overconfidence.
438 HAMILTON, *supra* note 30, at 111-16.
439 *Id.*
440 *Id.*
441 KEITH, *supra* note 402, at 45-72.
442 *Id.* at 88-94.
443 HAMILTON, *supra* note 55, at 111-16.
444 *See id.*
445 *See* SUNSTEIN, *supra* note 26, at 25 (describing the results of a survey of scientists, which revealed surveyed scientists believed technological advancements such as air travel and vaccines would have been prevented if the precautionary principle governed).

engineering feats that now seem commonplace.[446] Yet even those feats had setbacks—and in solar radiation management, setbacks are more dangerous than in any other area outside of nuclear research.

In light of the Icarus problem, however, the legal requirements discussed above in the context of the hell broth problem take on a different significance. The decision to deploy solar radiation management is significant. The Espoo Convention's demand that it be put to a debate is therefore meaningful both legally and intuitively.[447] If the very existence of life on Earth hangs in the balance, the solution should withstand public scrutiny instead of being made by a single company or state in secrecy.

### *C. Trigger Points and Exit Strategies*

Although the problems of solar radiation management are real, they can be overcome by designing the correct legal infrastructure for deployment. This section examines three principles that must guide any such market mechanism. First, solar radiation management must be deployed only once there is a clear exit strategy. Second, this exit strategy should determine the trigger point at which solar radiation management could be deployed. Third, solar radiation management should, in keeping with the recommendation of one of the leading scientists in the field, be ramped up slowly and ramped down slowly to control its effects and side-effects to the best of our abilities.[448]

A market mechanism may not be necessary to raise funds, since the cost of deploying solar radiation management is relatively low. But a market mechanism provides needed regulatory oversight by restricting how solar radiation management can be deployed while allowing solar radiation management technologies to be researched. The mechanism below assumes the eventual unilateral decision to start using the technology and sets out how such unilateral action could credibly be managed without tripping existing legal strictures that would prohibit deployment of the technology.

#### *1. Following Ariadne's Thread*

The same myth that brought us Icarus teaches us another simple lesson: if you want to escape a labyrinth, it is helpful to have a guiding thread.[449]

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[446] *See id.*

[447] Reynolds, *supra* note 13, at 93-94.

[448] KEITH, *supra* note 402, at 86.

[449] OVID, *supra* note 437, at 187. In the story of the Minotaur, Ariadne laid down a guiding thread in the labyrinth for Theseus to follow so that he might safely navigate its passages.

Before we deploy a potentially problematic technology, we should figure out how to stop deploying it.

The exit strategy for solar radiation management is clear. Solar radiation management can safely be undone when both flow and stock of GHGs have been reduced to safe levels.[450] Thus, we should not deploy solar radiation management without (1) a strategy for mitigating GHG emissions[451] or (2) a plan for removing GHGs from the atmosphere to get to net negative GHG emissions and thereby prevent an unsustainable spike in temperatures upon removing solar radiation management technology.[452]

The exit strategy for solar radiation management thus highlights that solar radiation management can be used only when there are tools available to commit to meaningful GHG mitigation and removal.[453] Even though solar radiation management technology must be available before mitigation and removal strategies have fully taken effect, solar radiation management must be used last rather than first. Geo-markets thus are an integrated design solution rather than a cafeteria menu.

### *2. Trigger Points*

The key benefit of using solar radiation management in combination with the carbon removal geo-market is that this market helps set trigger points for when to deploy solar radiation management. As a global rule, we should use solar radiation management only when Paris Agreement mitigation commitments, taken together with the carbon removal and carbon mitigation geo-markets, have established binding targets for GHG removal that, when reached, would avoid catastrophic results when solar radiation management technology is turned off.[454] Solar radiation management should be used only as a stop gap measure when the end point is reasonably in sight and should not be deployed before such commitments are in place.[455]

Importantly, these mitigation and removal commitments need not yet be met so long as the commitments are binding. In the context of the carbon removal geo-market, it would be enough for a government to have issued a license for carbon removal and agreed itself to purchase the requisite production to meet its removal commitment or required third parties to do so. Because geo-market transactions create binding

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450 *See* KEITH, *supra* note 402, at 136-37.
451 HAMILTON, *supra* note 30, at 71.
452 *Id.*
453 *See* KEITH, *supra* note 402, at 136-37.
454 HAMILTON, *supra* note 55, at 71.
455 KEITH, *supra* note 402, at 134.

performance commitments on the state, this prospective reduction can be credited in assessing whether the state has done what it could to meet its pro-rata share of emission reductions.

As it stands, these trigger points alone do not solve the hell broth problem. Thus, the deployment of solar radiation management as it currently stands probably is wrongful under existing international environmental law treaties governing atmospheric pollution. Users of the technology thus need a legal justification—either collective action or a circumstance precluding wrongfulness—to violate these norms.[456]

The procedurally easiest solution would be to put such questions to a multilateral treaty mechanism. As one commentator explained:

> Clearly, CLRTAP and its current Protocols—like current legally binding international law—do not address climate engineering per se. However, given [its] definition of pollution, a new Protocol to govern climate engineering, especially those methods that would operate by introducing substances into the air, would be within the scope of CLRTAP.[457]

But a truly multilateral solution may be a pipe dream. The negotiation of the Copenhagen Agreement in 2009 provides a case in point. Even though that Agreement was merely political rather than legal, its formal adoption as part of the Copenhagen proceeding was scuttled by a vanishingly small minority of states despite its significant, widespread, and representative support.[458] If a political agreement could not muster the necessary support, a legal agreement is likely harder still to adopt. And the current political environment does not inspire confidence in multilateral diplomacy, since multilateral diplomacy is not a tool the current U.S. administration seems much inclined to use.[459]

But can a state unilaterally set its own trigger point for deploying solar radiation management? What procedures must it follow to do so?

First, states could argue that the failure of collective action to resolve climate change provides a legal justification for unilateral action.[460] In

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456 *See* Reynolds, *supra* note 13, at 72-73 (suggesting that geoengineering would fall within the remit of a future protocol under CLRTAP); JAMES CRAWFORD, THE INTERNATIONAL LAW COMMISSION'S ARTICLES ON STATE RESPONSIBILITY 160-68 (2002) (discussing circumstances precluding wrongfulness).

457 Reynolds, *supra* note 13, at 73.

458 BODANSKY ET AL., *supra* note 64, at 76.

459 Kristen Boon, *President Trump and the Future of Multilaterism*, 31 EMORY INT'L L. REV. 1075, 1076 (2017).

460 It is important to understand why I am looking to unilateral action rather than a multilateral solution. The answer lies in a soft understanding of coordinated unilateralism as opposed to a true or adversarial unilateralism. A full defense of the kind of coordinated unilateralism advocated here is beyond the scope of this Article. Still, this Article advocates for the kind of "soft" unilateralism that is logically at the heart of every coordinated action by multiple persons. Coordination entails

fact, unilateral action on solar radiation management could eventually foster broader networked engagement. And the trigger point approach outlined above, which focuses on the reversibility of solar radiation management, could be modified for each state. Each state would look to its own trigger point, which it would reach when it has met its pro-rata share of GHG reductions.

Second, states could argue that a circumstance precluding wrongfulness—a plea of necessity, similar to a claim of self-defense—provides a legal justification for unilateral action. Professor Gardiner treats a state's right to act unilaterally under the rubric of the right to self-defense. He notes that states "are not required to completely ruin their own lives in order to comply with climate justice."[461] He further explains, however, that "this right is sharply limited" and "can be invoked only when there are no intermediate policies."[462] Although Professor Gardiner's reference to self-defense is legally imprecise, its intuitive appeal finds a legal foothold in the circumstance of precluding wrongfulness. A plea of necessity lies if the state's otherwise wrongful conduct is "is the only way for the State to safeguard an essential interest against a grave and imminent peril."[463] As the International Court of Justice recognized in *Gabcikovo-Nagymaros*, ecological threats can in fact be the predicate for a plea of necessity.[464]

First, whether solar radiation management is the *only* way to safeguard the ecological interest of the deploying state echoes Professor Gardiner's requirement that states have "no intermediate policies."[465] A state must have excluded all other reasonably available means of rectifying the problem. For example, a state would not be entitled to deploy solar radiation management if it had failed to reduce its GHG emissions according to its fair pro-rata share to meet the Paris Agreement target of stabilizing global temperatures at well below 2°C above pre-industrial levels.[466] Once a state had in fact so committed to reducing its emissions and had taken meaningful steps to implement its commitments, the state

that each actor has the unilateral power to act and makes a unilateral choice to coordinate. Sourgens, *supra* note 255, at 138-40. Any networked solution to global governance is premised upon this ultimate reservation of unilateral power. *Id*. And it is the independent choice by each actor to embrace the coordinated result which makes networked solutions so "sticky" or resilient against political attack. Harold H. Koh, *The Trump Administration and International Law*, 56 WASHBURN L.J. 413, 446 (2017).

461 GARDINER, *supra* note 46, at 403.

462 *Id.*

463 Int'l Law Comm'n, Rep. on the Work of Its Fifty-Third Session, UN Doc. A/56/10, at art. 25(1)(a) (2001) ("Articles on State Responsibility").

464 Gabcikovo-Nagymaros Project (Hung. v. Slovk.), Judgement, 1997 I.C.J. 7, 41 (Sept. 25).

465 GARDINER, *supra* note 46, at 403.

466 BODANSKY, *supra* note 64, at 214.

might still have to take other reasonable actions to avert climate change short of starting solar radiation management. Different states could have different trigger points for deploying solar radiation management, all things being equal. Still, a state would be entitled to begin deployment upon meeting its pro-rata share of emission reductions.[467]

Second, a state must show that solar radiation management is needed to protect against the grave and *imminent* peril of climate change.[468] As the Court explained in *Gabcikovo-Nagymaros*, "[t]hat does not exclude, in the view of the Court, that a 'peril' appearing in the long term might be held to be 'imminent' as soon as it is established, at the relevant point in time, that the realization of that peril, however far off it might be, is not thereby any less certain and inevitable."[469] If a state demonstrates that a peril is certain and inevitable, it need not wait to take measures to address the threat.

Given the current state of scientific knowledge, it is unclear when, exactly, tipping elements will be crossed.[470] But it would be unfathomable for international law on the one hand to require states to take IPCC's warnings seriously under the Paris Agreement and on the other hand to deny IPCC projections sufficient certainty to permit states to take necessary action to heed the warning expressed in them.[471] The closer we come to the projected tipping elements, the more certain and inevitable the peril becomes—particularly if it appears that other states have not taken sufficient steps to avoid these tipping elements in time—and the more reasonable and justifiable unilateral state action becomes.[472]

Finally, a state must not "seriously impair an essential interest of the State or States towards which the obligation exists, or of the international community as a whole."[473] A state would reasonably have two obligations in this regard. The first is to abide by the procedural obligations established in the Espoo Convention and other treaties to share information and permit publics affected to contribute to the debate about using solar radiation management prior to deploying the technology.[474]

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[467] *See* ZAHAR, *supra* note 66, at 15-16. The calculation of what this pro-rata share should be is a theoretically challenging question. For a discussion of these challenges, *see* GARDINER, *supra* note 46, at 421-26. The pragmatically simplest solution is likely to look at per capita emission reductions as a baseline for assignment of national reduction targets to meet Paris Agreement goals for current purposes. That idea, however, will require further defense in a later article.

[468] *See* Craig Martin, *Challenging and Refining the 'Unwilling or Unable' Doctrine*, 52 VAND. J. TRANSNAT'L L. 387, 415-23 (2019).

[469] Gabcikovo-Nagymaros Project (Hung. v. Slovk.), 1997 I.C.J. at 42.

[470] IPCC, *supra* note 4, at 12.

[471] *Id.*

[472] *Id.* at 7-12.

[473] Articles on State Responsibility, *supra* note 463, at art. 25(1)(b).

[474] Reynolds, *supra* note 13, at 94.

This means that the state in question must commission or conduct a robust environmental impact assessment with regard to its planned conduct, make the results available, and engage in meaningful exchanges about the environmental impact assessment with third states and affected communities.

The state's deployment also must be proportionate. In such circumstances, the trigger point would permit a ramp up of solar radiation management without the risk of claims by slower states that the deployment is internationally wrongful.[475] The deployment would be permissible to the extent that it is proportionate to the state's emissions reduction commitment.[476] This means that no state could claim that the deployment by others would violate its international legal rights—thus also providing liability protection.

Critics may counter that the plea of necessity is not available as a justification under international law in the climate change context because "[t]he State has contributed to the situation of necessity" by producing GHG emissions.[477] While it is true that all states have contributed to climate change, the necessity here arises from the failure to reduce emissions by a date certain, not from the initial production of emissions.[478] If a state meets its pro-rata share of the emission reduction goal, it is not contributing to the situation of necessity and thus would not be precluded from pleading necessity.[479]

If circumstances become sufficiently dire, states will likely resort to Professor Gardiner's self-defense rationale. The plea of necessity approach outlined here sets out a means to do so that is both pragmatic and narrow rather than foreclosing self-defense or necessity in the climate context as a matter of principle.

### *3. Tortoise, not Hare*

This leads to the final synergy between geo-markets and the eventual deployment of solar radiation management. Solar radiation management should be deployed like the tortoise—not like the hare—in the fabled race between the two animals.[480] If solar radiation management is deployed too quickly, or drawn down too quickly, the environmental risks created

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475 BODANSKY ET AL., *supra* note 64, at 78-82 (discussing the dysfunction of climate voting procedures in the UNFCCC context).

476 CRAWFORD, *supra* note 476, at 167.

477 Articles on State Responsibility, *supra* note 463, at art. 25(2)(b).

478 IPCC, *supra* note 4, at 12.

479 *See* GARDINER, *supra* note 46, at 403.

480 Aesop's Fables, The Tortoise & the Hare, available at http://www.read.gov/aesop/025.html.

by the new technology increase exponentially.[481] The use of solar radiation management therefore works best if there is an earlier rather than a later trigger point at which it can be tested and deployed.

The slower approach also—perhaps paradoxically—requires an earlier commitment to its development.[482] Climate scientists have warned about the danger of reasonably close tipping points in the climate system.[483] According to the best available scientific knowledge, then, the use of solar radiation management will become essential at some point in the near future.[484] That knowledge is unlikely to change drastically in the window ahead—and, in any event, science is unlikely to suggest that there is significantly more time to act to avoid a tipping point.

### *D. The Service Contract Model*

How can we use an energy law-inspired model to create a solar radiation management geo-market that satisfies the design criteria outlined in the last section? This section argues for looking to risk services contracts as a model. These contracts are used by some countries such as Brazil in order to receive the benefit of the engineering know-how of leading energy companies without giving up control of either the process of development or the eventual operation of the resulting project.[485] Risk services contracts thus meet solar radiation management's twin needs for constant governmental supervision and involvement of private sector expertise and capital.

In general, the risk services contract model sets out that the host country of a project selects a service provider to conduct exploration and development of oil and gas reserves in a specific contract area.[486] The service provider typically is an international oil and gas company with significant engineering expertise.[487] The risk services contract sets out the basic milestones that the service provider must achieve to meet its exploration obligations.[488] The service contract further makes clear that all information about the exploration process belongs to and must be fully shared with the state.[489]

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481 KEITH, *supra* note 402, at 86-88; HAMILTON, *supra* note 30, at 70-71.

482 KEITH, *supra* note 402, at 88.

483 IPCC, supra note 4, at 12.

484 *See id.*

485 Johnnie W. Hoffman, Jr., *The Service Contract as a Vehicle for International Petroleum Exploration and Production*, ROCKY MTN. MIN. L. FOUND. SPECIAL INST. CH. 14 (1994).

486 *Id.*

487 *Id.*

488 *Id.*

489 *Id.*

If the service provider finds oil and gas reserves in the contract area, the service provider then works with the government on a development plan.[490] The government thus is involved in the planning and supervision of the eventual development.[491] It also has full approval rights, since the project formally and functionally belongs to the government and not the contractor.[492] Terms differ as to how development is paid for. Typically, however, the service provider "carries" the state through development, meaning that it pays for development in return for later payment from production.[493]

Once development is complete, the service provider turns over operation of and production from the contract area to the state. The service provider then receives payment from production based on a pre-determined formula for a period of years.[494] This formula repays the service provider for its expenses and includes a risk premium as a form of profit participation.[495] Typically, the payment period is around 20 years.[496] The service provider therefore reaps the benefits of its efforts without actually operating the project.

Since the risk services contract model currently is used only in domestic settings, it will need to adapt to international needs in the solar radiation management context. Specifically, as outlined above, states will have treaty-based information sharing obligations should they wish to develop and deploy solar radiation management unilaterally. This means that states will need to continuously communicate information they receive from their contractors to relevant scientific and regulatory bodies. As it stands, the legal obligation involved would suggest that this information be shared formally with the secretariats of the UN Framework Convention on Climate Change and its Paris Agreement, the 1985 Vienna Convention and its Montreal Protocol, the CLRTAP, the UN Bio Diversity Convention, and IPCC so that these institutions can in fact meaningfully participate in discourse about the technology well ahead of any potential deployment.[497]

Further, the Espoo Convention suggests a right to discourse participation by affected publics. Functionally, this suggests that information also be shared between national authorities through global

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490 *Id.*

491 OWEN ANDERSON ET AL., INTERNATIONAL PETROLEUM TRANSACTIONS 482-501 (3rd ed. 2010).

492 *Id.*

493 *Id.*

494 *Id.*

495 *Id.*

496 *Id.*

497 *See* IV.C, *supra*.

governance networks of the respective national environmental regulators. These environmental regulators should follow their own respective notice and comment procedures to receive feedback from the public and then communicate potential concerns relating to the deployment of solar radiation management to their respective counterparts.[498] While the ultimate decision under the unilateral action paradigm would lie with the home state proposing action, the home state would have to show that it in fact considered these inputs in its own decision-making processes ahead of actual deployment or run the risk of not benefiting from the plea of necessity justification should a third state claim that the deployment of a solar radiation management was internationally wrongful.[499]

*1. Research as "Exploration"*

The first phase of any solar radiation management market must be a market mechanism for research.[500] The likely equivalent for this research phase in the risk services contract model is exploration.[501] Both concern a process of discovery. In the risk services contract setting, the process of discovery looks for oil and gas.[502] In the context of solar radiation management, the process of discovery looks for technology that can limit inbound solar radiation. In both cases, both the government and the contractor determine that there is a reasonable prospect of success—the government by choosing the area and the contractor by bidding for the contract in the first place. In both instances, however, an element of risk remains. The research so conducted, whether successful or unsuccessful, would then need to be communicated internationally by the government in order to satisfy procedural obligations of the state in question ahead of further development to provide opportunities for scrutiny and objections to be raised and assessed.[503]

For more mature solar radiation management approaches such as sulfuric acid/sulfate aerosols, states could follow current risk services contract practice that the contractor carries the full cost of "exploration"—in this case, an exhaustive projected environmental impact assessment. When research is more or less certain to arrive at the desired results, companies will finance the cost of research. In fact,

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498 *See* Sourgens, *supra* note 76 (discussing the functioning of global governance networks in the climate context).

499 *See supra* sub-section C.

500 KEITH, *supra* note 402, at 80-81.

501 *See generally* HOFFMAN, *supra* note 485.

502 *Id.*

503 *See* IV.D, *supra*.

companies are already investing in this fashion.[504] If a government were looking for alternative forms of solar radiation management, it probably would need to improve the compensation structure to incentivize companies to participate.

At the end of the research, the contractor will communicate its results to the government consistent with the risk services contract model.[505] The state then will determine whether or not the "exploration" was successful by reviewing the contrator's submitted data.[506] In both the original setting and the research setting, this requires verification. This verification, consistent with best practices in both industries, would be made by according to objective, pre-agreed criteria. According to the Espoo Convention, the contractor's communications to the state must contain enough environmental modeling to permit potentially affected people to study the data and comment on risk factors.[507] This process must be open, transparent, and provide a full work up of methodology and findings in a manner that is open to the global public.[508] The state regulator's decision about the success of the exploration should also allow the global public to comment on the findings as soon as possible.[509] Once a finding has been made that exploration or research was in fact successful, the next phase would begin.

*2. Testing as "Development"*

The next phase in a solar radiation management project following research is small-scale testing.[510] Research principally relies upon modeling.[511] This modeling can anticipate only some of the relevant repercussions of the eventual deployment of a solar radiation management approach.[512] Thus, companies must still test the approach on a small scale.

The testing of research creates potential issues under current international law. Testing causes transboundary harm if deployment of the technology causes harm. As discussed above, this harm would potentially fall within the scope of existing treaties to protect the integrity

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504 *See* Randy Showstack, *Study Will Examine Risks and Benefits of Climate Interventions*, EOS (May 13, 2019), https://eos.org/articles/study-will-examine-risks-and-benefits-of-climate-interventions.

505 ANDERSON ET AL., *supra* note 491, at 482-501.

506 *Id.*

507 SANDS & PEEL, *supra* note 121, at 667-71.

508 *Id.*

509 *Id.*

510 KEITH, *supra* note 402, at 81-84.

511 *Id.* at 83.

512 *Id.*

of the ozone layer or bio-diversity.[513] Thus, either the test should be at a small enough scale to avoid causing cognizable transboundary harm or a state must have a justification to explain why it is entitled to test and cause harm. To the extent that it has made sufficient commitments to meet its pro-rata share of emission reductions, the state probably would be in a position to argue that its conduct is a matter of necessity, meaning that it would not be subject to liability even though the conduct could be wrongful in other circumstances.[514]

To the extent that any one affected group, state or civic community, wishes to engage in public discourse ahead of a decision to authorize testing, the early communication of data and a notice and comment procedure in the home state would enable a full debate about environmental risks at the earliest possible time.[515] Communicating exploratory data thus permits an orderly development of discourse ahead of any potentially damaging action and, hopefully, permits meaningful consensus to form through engagement ahead of testing.[516] It also may assist in setting benchmarks for testing to further inform debate before any deployment stage.

Following the risk services contracts approach, testing may be treated as development.[517] Accordingly, the contractor should bear the cost of such testing.[518] The risk element of the risk services contract is that production is not ultimately possible.[519] As testing is part of this risk in the solar radiation management setting in the same way that development is part of this risk in the petroleum setting, the state should pass the initial cost burden to the contractor, to be recovered if the testing is successful.[520] Consistent with the risk services contract model, the state would thus be carried through the testing phase.[521]

Determining whether development or testing was a success calls for objective validation. The rules governing the research stage again would be applicable in this context.[522] This would be consistent with best practices as well as with international legal requirements to allow potentially affected people a voice ahead of decision-making.[523]

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513 *See supra* sub-section C.
514 *Id.*
515 *See* SANDS & PEEL, *supra* note 121, at 667-71.
516 *See id.*
517 *See* KEITH, *supra* note 402, at 84-85.
518 ANDERSON ET AL., *supra* note 491, at 482-501.
519 *Id.*
520 *Id.*
521 *Id.*
522 *See* IV.D.1, *supra*.
523 SANDS & PEEL, *supra* note 121, at 667-71; KEITH, *supra* note 402, at 116.

### 3. *Deployment as "Production"*

The key benefit of the risk services contract model is that deployment of the technology rests in the hands of the state once development is completed. Because production in the risk services contract model is handled by the state,[524] deployment of solar radiation management—the equivalent of production in this context—similarly would fall to the state.[525]

This has several advantages. First, it avoids the impression that the future of the planet has been abdicated to commercial interests.[526] Instead, the environment remains in the hands of the global political community.[527] Second, states are better equipped to deal with issues of deployment through international treaties.[528] There is thus a limited risk that the process of solar radiation management would be governed outside the existing climate networks.

The decision of how, when, and for how long to deploy the technology is a political decision best left to political actors. These political actors are not nakedly self-interested in deployment. They do not earn a fee for the continued deployment of the technology. The opposite may be the case—deployment is a cost rather than revenue. This would limit the profit motive to continue deployment when it is no longer needed.

To make such decisions, the state must be sufficiently well-trained in the technology to deploy and monitor and regulate deployment. This supports the public nature of solar radiation management in that companies cannot hide as proprietary what must be disclosed to allow proper deployment. And it places the state in a position to monitor and regulate side-effects in a more efficient manner than if the company itself were left to implement radiation management.

## E. *Pricing*

Pricing mechanisms must take four factors into account. First, prices should be tied to efficacy of the technology used to achieve the desired radiation management effect to pinpoint intervention as narrowly as possible.[529] Second, prices must incentivize the development of the best available technology rather than the cheapest technology.[530] Third, prices

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524 ANDERSON ET AL., *supra* note 491, at 482-501.

525 KEITH, *supra* note 402, at 85-86.

526 *See* HAMILTON, *supra* note 55, at 146-48 (discussing potential governance risk factors).

527 *Id.* at 177.

528 *Id.* at 147-49; *see also* Reynolds, *supra* note 13, *passim* (discussing potentially applicable international treaties).

529 KEITH, *supra* note 402, at 86-87.

530 *See id.* at 107 (discussing cost concerns regarding safer alternatives to sulfuric acid).

should be sensitive to the environmental harm done by different technologies and internalize those harms as costs so as to incentivize the development of less harmful technology.[531] And finally, prices must account for the implications of deployment and non-deployment from both the government's and the contractor's perspective to create a stable market place.

First, pricing should be tied to a measurable reduction of solar radiation. The price should be negotiated for the desired reduction in radiation so long as the reduction falls within a certain predetermined band of technical specifications.[532] The pricing mechanism should be sensitive to the failure of the mechanism to hit the predetermined target in either direction by lowering the price for any over- or under-management of radiation, as both effects are potentially dangerous.[533] This price could be expressed in a formula of dollars per reduction times a fraction of the deviation from the target range. In other words, the government should set the price it is willing to pay on the basis of the productivity of the technology used. This will incentivize the development of the most accurate and the most effective technology.

Second, the price for radiation management should incentivize the development of superior technology. As it currently stands, geo-engineers have hypothesized that inert particles could be designed, engineered, produced, and deployed that have almost no environmental impact.[534] The problem is that the production of these particles may be too expensive when compared to other available technologies.[535] The pricing structure therefore should reward ambition to develop better technology.

The correct pricing for solar radiation management is nearly impossible to set. In theory, such a price would be set on the basis of what a willing buyer would pay a willing seller for the technology in question. But because the right technology can protect the entire planet against catastrophic and even fatal climate change impacts, determining a fair price is a challenge.

A high price for solar radiation management would serve as a disincentive to over-rely on a technology that is otherwise unable to remove the risk of climate change. The cheaper solar radiation management technology is, the greater the incentive to use it for longer

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531 *Id.*
532 *Id.* at 91.
533 *See* HAMILTON, *supra* note 55, at 71.
534 KEITH, *supra* note 402, at 107.
535 *Id.*

periods of time than may be advisable given its risks.[536] Setting a higher price thus would discourage prolonged use of the technology.

A different way to calculate the price would be to ask how much we would be willing to pay to avoid the side effects caused by sulfuric acid released into the atmosphere by existing solar radiation management technology. Though crude, perhaps a ten times multiple of the existing cost structure of sulfuric acid aerosols would be a reasonable target. Current technology would be an effective shield against climate change impact at $1–6 billion per year.[537] Increasing this figure by a factor of ten would make up to $60 billion a reasonable price for incentivizing the development of new and better technology. This amounts to less than half the annual expenditure on the U.S. navy ($160.8 billion).[538]

Third, the price should reflect the environmental impact of the solar radiation management technology. Thus, the full price should only be payable when solar radiation management technology is projected to have negligible environmental impacts. To the extent that significant environmental impacts result, states should reduce the price to reflect this cost. As a benchmark, one could use the price for current technology, plus a reasonable rate of return for the full development of that technology and a repayment of development costs.[539] To achieve a higher price, technology would need to demonstrate a proportionately smaller environmental impact. The price would then be adjusted between the two ends of the scale of zero environmental impact (full price) and the impact of sulfuric acid aerosol deployment (sulfuric acid price) by placing it on the environmental impact scale between the two.

In order to disincentivize shopping on the basis of price, the difference between the price paid to the contractor and the "full price" payable for perfect technology should be paid into an adaptation fund. This fund should be managed in order to pay for adapting to the damage caused by the deployment of the technology. It would similarly represent liability insurance for the use of the technology by serving as a fund from which victims of the technology could be compensated for successful claims.

This funding mechanism is consistent with the ethical recommendations of Professor Gardiner. In *Perfect Moral Storm*, he notes that invocations of self-defense "impl[y] a need for compensation"

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536 *Id.* at 150-51.

537 *Id.* at 99-100.

538 David Larter, *The US Navy will hit a milestone ship count in 2020*, DEF. NEWS (Mar. 12, 2019), https://www.defensenews.com/naval/2019/03/12/the-us-navy-will-hit-a-milestone-ship-count-in-2020-pours-money-into-sailors-subs-and-unmanned-tech/ (Navy requesting "$160.8 billion in base funding").

539 *See* KEITH, *supra* note 402, at 99-100 (setting out current cost models).

to the extent that intermediate policies are avoided.[540] In this case, the choice of solar radiation management technology is very much a question of which intermediate policy is chosen.[541] Thus, the choice of a reasonably more harmful technology that is cheaper to deploy must carry with it an inherent compensation mechanism to be just.[542] The pricing mechanism must be designed to account for that possibility.

Finally, the pricing mechanism must provide minimum compensation to the contractor upon completion of the development stage. The contractor must be able to depend upon the payment obligation of the state when it has completed its work in order to finance research and development. Thus, even if the technology is never deployed, a minimum price must be set in advance and paid upon completion of development and testing. The price should immediately reimburse the contractor for all development costs (including costs for technological avenues not ultimately used by the contractor) and should further pay the contractor a reasonable return upon investment.

On the other hand, there should be incentives in the pricing structure for the state to stop deployment at the earliest appropriate time. The state should not be bound to a fixed payment period to encourage the non-deployment of technology and the cessation of deployment of technology that is antiquated. Thus, the price for actual use and radiation reduction should only be paid for the periods in which the technology is actually used instead of for periods of time in which the state chooses not to deploy any technology or to deploy a different technology.

This pricing structure enables the state to contract with multiple contractors at the same time. The completion of successful testing would mean that each contractor would receive a reasonable return on investment. But because the state ultimately would deploy only the best technology, the pricing structure would create incentives for contractors to develop both the most effective and the most environmentally friendly means of solar radiation management.

The solar radiation management geo-market would thus seek to replicate the use of economic market forces to fight climate change in much the same way as the previous two geo-markets for carbon removal and carbon mitigation. It creates economic incentives to invent the most efficient technology to combat climate change. It does not require the state to pay at the front end when technology is not proven but instead requires the state to pay only at the back end when technology has proved

[540] GARDINER, *supra* note 46, at 403.
[541] KEITH, *supra* note 402, at 105-07.
[542] *See* GARDINER, *supra* note 46, at 403.

that it can in fact achieve the promised goals. This means that the solar radiation geo-market, like other markets, brings to bear additional forces beyond the public sector to create the public goods of climate protection in a manner that would not be affordable or efficient for the government to do on its own.

While the solar radiation management geo-market relies on market forces, it does not make them the be-all, end-all for climate action. It leaves the management of climate policy and solar radiation management in the hands of the state. It thus provides a reasonably safe and reasonably accountable mechanism to deliver climate change responses to world society. Rather than forcing a choice between market or government, energy or environment, the geo-market seeks to marry the best of each of these perspectives in the service of achieving the goal set out for the entire world at the end of the Paris Agreement negotiations: limit the increase in average global temperatures to no more than 2°C, and hopefully less than 1.5°C, above pre-industrial levels.[543]

## Conclusion

This Article has argued that climate governance processes can be significantly advanced through the introduction of market forces. Creating three different markets can assist in overcoming the current challenges in reducing GHG emissions sufficiently by 2030 to avoid run-away climate change scenarios. Specifically, governments and private actors should create robust markets for the removal of GHGs from the atmosphere and use market prices from the removal context to assist in mitigation efforts by paying out existing coal-fired power plants. This approach is preferable to the current mitigation paradigm for two reasons. First, the carbon removal geo-market can overcome our significant reliance on existing fossil fuel energy infrastructures that cannot easily be compensated for by mitigation efforts alone, since mitigation measures impose a politically unacceptable level of pain on vulnerable populations. Removal technologies can overcome this problem by redistributing how the costs of net reductions in GHG emissions are borne. Second, the carbon removal geo-market is better at addressing the root cause of climate change—the total accumulation of GHGs in the atmosphere, not yearly emissions of GHGs. Thus, it will help manage the dangerous effects of current levels of climate change more effectively over the long term.

This Article has also proposed an infrastructure for deploying solar radiation management technology. Specifically, it lays out how

[543] Paris Agreement, *supra* note 63, at art. 2(1)(a).

policymakers can and must anticipate when solar radiation management can be turned off again before beginning to use the technology. By integrating geo-markets, this Article therefore has provided a means to overcome some of the more challenging problems facing geo-engineering governance.

Geo-markets are not a panacea. The costs of implementing geo-markets are significant, and they suggest that mitigation efforts must continue apace for climate change challenges to be overcome by 2050. But even though geo-markets are not capable of carrying the entire energy infrastructure, they will play a vital role in resolving climate change. Geo-markets therefore should be seen as operating in tandem with and supporting broader decarbonization efforts rather than substituting for them.