Our Two Climate Crises Challenge: Short-Run Emergency Direct Cooling and Long-Run GHG Removal and Ecological Regeneration

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Abstract

We are facing both a short-term emergency cooling crisis and a long-term GHG drawdown planetary ecological crisis. We must address both. The first requires emergency direct cooling, or temporary "triage" or a "tourniquet, for our bleeding planet". The second requires rapid GHG emissions reductions and drawdown and natural planetary regeneration that realistically will take at least a few decades and may take a century or more. Conflating the challenge and opportunity of the second crisis with a response to the first crisis will not produce a rapid and credible global response to the second crisis because of structural economic inequity and fossil fuel dependency that is deeply embedded in the current global economy. Realistically, we need emergency direct cooling to address the first crisis and a long-term binding global cap and trade "emissions trading system" (ETS) to address the second. The Florin proposal that conditions SAI direct cooling on credible GHG emissions and drawdown is a step in the right direction, but omits other direct cooling methods and effectively makes the deployment of SAI contingent on a global ETS that may not be possible before the deployment of SAI becomes necessary. Rather than conflating our two climate crises, or conditioning the solution of the first on a solution to the second, we need to address both on an emergency basis by putting all options on the table as called for in the HPAC proposal.

Introduction

We have, not one, but two climate crises: a) a short-run global warming emergency causing amplified polar warming and global ice melt that currently causing an unraveling of the global climate and risks pushing us over the edge to irreversible climate collapse within decades, and b) a long-term Green House Gas (GHG) removal and ecological regeneration crisis that will take at least several decades and possibly a century or more resolve.

This paper attempts to discuss and outline a strategy for addressing both. It has five sections: I) Our Two Climate Crises, II) Background Political Framing, III) The Limits of the Current Moral Suasion and Breakdown Strategies, IV) How Can Short-Run Emergency Direct Cooling, and Long-Run GHG Removal and Ecological Regeneration be Achieved, and V) Conclusion.

I. Our two Climate Crises

The current average global warming level of 1.2 degrees C above pre-industrial is causing irreversible and catastrophic damage to us and other species. If we fail to try to immediately cool our planet, and particularly the polar and Himalayan regions (the "third pole"), we will forego the possibility that at least some of this catastrophic devastation could be reduced or avoided. At the current level of warming we may begin to cross the first climate tipping point, a melting of summer Arctic sea ice, as early as this decade, see Figure 1, below.

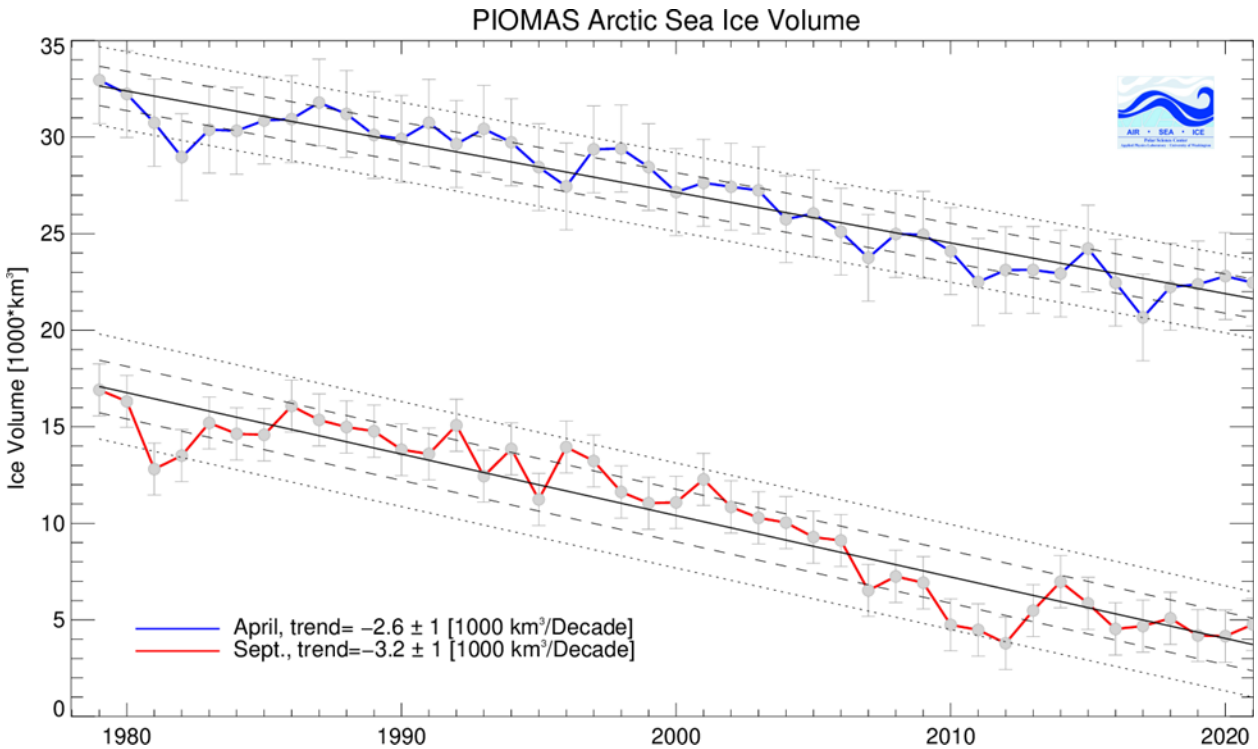

Figure 1: 1979-2021 Monthly Sea Ice Volume from PIOMAS for April and Sep.

Source: http://psc.apl.uw.edu/wordpress/wp-content/uploads/schweiger/ice_volume/BPIOMASIceVolumeAprSepCurrent.png. Downloaded 12/26/2021 from the Polar Science Center, Applied Physics Laboratory, University of Washington, USA.

Estimates included in (Pistone et al 2019), and corroborated by multiple other studies using different data and methodologies cited in this paper, suggest that crossing this tipping point would have a radiative forcing impact equivalent to that of 25 years of GHG emissions at current rates. Resetting this estimate to a 2016 baseline reduces this to 17.3 years of additional GHG emissions from 2016 to a completely ice-free summer Arctic (Baiman 2021, footnote 6).

The global climate unraveling, much of which may be directly or indirectly attributed to Arctic amplification (McSweeney 2019), is already increasing the number and severity of catastrophic climate events and raising commodity prices. Though it is impossible to directly link any single catastrophe to climate change, a 2021 report by Christian Aid found that the six years with the costliest (over $ 100 billion) climate disasters have occurred since 2011 (Christian Aid 2021), and a recent Wall Street Journal article also notes that bad weather is a major factor in the 2021 run-up in commodity prices in the US and globally (Dezember 2021).

There is no doubt that in the long-run, until we are able to stop emitting and drawdown atmospheric GHG by well over a trillion tons of CO2eq – an effort that will take decades and possibly more than a century (Baiman 2021, Figure 1 and footnote 9), these impacts will worsen. A November report by Swiss Re, one of the world's largest reinsurance companies, estimates that at the current trajectory, global temperature is likely to rise to 2.6 degrees Celsius above pre-industrial levels and will reduce world GDP by $23 trillion by 2050 (Swiss-Re 2021). Poor countries will suffer the most. To put this in perspective, current (2020) world GDP is estimated at $84.54 trillion.[1] In the Swiss Re scenario, the potential GDP of the US, UK, Canada, and France would decline by 6-10 percent, while the GDP of Malaysia, the Philippines and Thailand would be reduced by one third. But these are most likely underestimates, as the Swiss Re report acknowledges that:

"Importantly, the framework does *not* consider tipping points, events such as the partial disintegration of ice sheets, biosphere collapses, or permafrost loss, that pose a threat of abrupt

[1] https://www.statista.com/statistics/268750/global-gross-domestic-product-gdp/

and irreversible climate change. This is because it is thought that tipping points will materialize well after the model horizon of mid-century only." (Swiss-Re 2021, p. 30).

The assumption that tipping points will not materialize until after mid-century (2050) is almost certainly incorrect. Based on the trend shown in Figure 1, we are on track to begin crossing the first tipping point, the complete loss of summer Arctic sea ice, by 2034.[2] Based pm the trends shown in Figure 1, by 2050, the Arctic will be ice free for several months. This will increase the risk of crossing other potentially more catastrophic tipping points, such as massive methane release from Siberian permafrost melting and a collapsed Atlantic Gulf stream – both related to Arctic amplification, that appear to also be starting far earlier than previously estimated (Lenton et al. 2019) (Kindy 2021).

For all these reasons it is imperative that we implement emergency direct cooling measures, with a particular focus on restoring or slowing ice melt in the polar regions (including the Himalayan "third pole"), immediately. We cannot afford to wait for three decades and probably longer, to achieve zero emissions and remove sufficient GHGs from the atmosphere to prevent continued and accelerating climate deterioration.

II. Background Political Framing

The dominant discourse on climate change has for many years been framed as a Manichaean battle. The "deny or do nothing" position, most prevalent in the US and a handful of other countries, has presumably weakened as calamitous climate events that can be traced to global heating occur more frequently. But the dichotomous, moralistic (fossil fuel use is an "original sin"), political left/right, existential fight for survival, framing continues to hold sway,

[2] Figure 1 indicates ice volume of about 4 (1,000 km3) in September 2021 and a trend of -3.2 (1000 km3) loss per decade. As 4/3.2=1.25, this suggests September zero ice volume in 2021+ 12.5 = 2033.5, or by 2034.

particularly in the US.

This frame has become dominant for good reasons. It contains kernels of truth. Special interests including fossil fuel interests, right wing billionaires, media moguls, and oligarchic elites, have conspired to deny the truth and block GHG mitigation and adaptation efforts. The resulting faltering political response, particularly at the critical global level, has been wholly inadequate and dispiriting. And of course, in an already unconscionably inequitable world, the poorest and most vulnerable have and will suffer the most.

Though this frame is understandable, it has become an obstacle to practical progress as it:

a) Does not offer hope, particularly in the face of repeatedly backsliding or inadequate political responses.

b) Frames climate change in purely moralistic or political terms ignoring objective embedded physical and social and political institutional infrastructure that blocks or slows GHG mitigation and adaptation regardless of morality or politics.

c) Fails to fully account for the imperative of lifting up standards of living for billions of people even as GHG emissions are reduced.

d) And most importantly offers no immediate relief for climate change induced suffering due to already "baked in" effects that will be ongoing and worsening even if GHG emissions are reduced to zero now, and does not recognize that addressing the climate crisis in the short-term time period dictated by the climate is a practical problem of applying *a technological tourniquet to a critically bleeding planet*, and of CDR and CCSS as well as mitigation and adaptation, within *existing* social and economic systems that themselves will take much longer to evolve.

An alternative frame will recognize that:

a) Closing the carbon cycle is a long run *opportunity* for human civilization to evolve from "industrial hunter gatherer" to a more equitable and prosperous Renewable Energy and Materials Economy (REME) "industrial cultivator" state (Eisenberger 2020) (Baiman 2021, Sections III-IV).

b) Fossil fuel use was not an "original sin" but the basis for modern industrial civilization and addressing the climate crisis is, at least in the short term, not fundamentally a moral and political problem, but a practical and technological problem that must be addressed within existing social and economic systems (Baiman 2021, Sections III-IV),

c) We must address equity or our efforts will fail (Section III b)).

d) During the critically important short-term (at least several decades but possibly much longer) transition period we must keep the climate from spiraling out of control by trying to apply an emergency "tourniquet" to try to slow or reverse the worst climate impacts, and particularly the first imminent Arctic sea ice melting tipping point (Section I).

An even more comprehensive framing can also be found in a proposal put forth by the Envisination group (Pearce et al, 2021). This plan estimates that regenerating land and ocean fertilization to prior levels of life could potentially "sequester" organic carbon equal to roughly 87% of the carbon necessary to achieve a sustainable global climate that is no warmer than 0.5 C above preindustrial by 2050. The rest of the sequestration would be roughly divided between natural geological methods such as rock weathering and biochar and basalt soil carbon enhancements, and mechanical methods performed by a REME economy with Direct Air

Capture (DAC) and other Carbon Capture Sequestration and Use (CCSU) technologies. Though DAC and other technological methods may be orders of magnitude faster and less land intensive than pure nature-based methods, this general proposal would address the broadly natural ecological devastation on multiple fronts incurred by "hunter gatherer" industrial civilization that will be needed for long run sustainable human and other species survival on the planet (Pearce et al, 2021, p. 67, 77) (Baiman 2021, 2020) (Desch, S. J. et al 2017).[3]

III. The Limits of the Current Moral Suasion and Breakdown Strategies

In addition to opposition by vested interests and misguided or corrupt actors, I believe that two other important factors are standing in the way of practical solutions to our short-run and long-run climate crises respectively:: a) disciplinary siloization, and b) real economic and political constraints to implementing a meaningful and rapid transition to a renewable and sustainable economy (Baiman, 2021).

a) Disciplinary Siloization

Climate scientists have been documenting this looming first climate tipping point and its abrupt and potentially catastrophic impact on the global climate for years but do not see themselves as responsible for proposing solutions. On the other hand, social scientists, who are focused on trying to develop plans and estimates for solutions, are focused on politics, economics, and technological change, that are rightly viewed as the fundamental locus and source of the problem

[3] Some DAC methods such as Klaus Lackner's "mechanical trees" are reportedly able to drawdown carbon 1,397 times faster than natural trees so that a "forest" of only 250 square miles of these trees (at 120,000 trees per square mile) could drawdown about one gigaton of CO2 a year (Baiman, 2021, p. 617).

and of potential remedies. Emergency Direct Cooling therefore falls outside the traditional scopes of both climate scientists who are focused on documenting and understanding climate change, and social scientists and engineers focused on GHGs emissions. The possibility and urgency of trying to do something to slow or reverse this first climate tipping point is not being addressed by any government or international body. This lack of action persists, despite relatively modest cost estimates of $ 1-10 B for the various proposals (Baiman 2021, Table 1, p. 8).

a) Political and Economic Constraints to Rapid Global GHG Removal

Two incidents vividly demonstrate the political and economic constraints to rapid GHG removal. The President of Ecuador offering to not exploit newly discovered oil reserves in the Amazon rain forests if the international community would reimburse Ecuador for forgone oil earnings, and after getting no response, moving ahead with oil extraction (Goldman 2017), and Norway (one of the most social democratic, environmentally responsible, and wealthiest (per capita) countries in the world) going ahead with exploitation of newly discovered north sea oil reserves using "green" technologies (Kottasovana 2020).

Aggregate data show that these economic and political constraints are not constrained to a small number of countries. Figure 2 below shows that in 2019 over 1.5 billion people (20% of the global population) lived in Europe and Central Asia or Sub-Saharan Africa, both excluding high income, or Other Small States, for which on average (weighted by population) 26% of total exports are fossil fuel exports that in 2019 generated approximately $ 149 billion of vital foreign exchange for these countries.

Fuel Exports as a Share of Total Exports and GDP (2019, 72 ECA, OSS, and SSA Countries)					
Country Name	**Country Code**	**Pop 2019 (millions)**	**Fuel Exports % Total Exports**	**Fuel Exports % GDP**	**Fuel Exports $ (millions)**
Europe & Central Asia excluding high income (ECA)	ECA	418.8	27.3%	9.1%	$85,733.1
Other Small States (OSS)	OSS	31.4	45.5%	26.3%	$43,037.8
Sub-Saharan Africa excluding high income (SSA)	SSA	1106.9	25.7%	6.1%	$20,181.8
Weighted Avg by Pop			26.5%	8.2%	
Total		1557.1			$148,952.8
Share of Global Total		20.2%			

Figure 2: Liquid Fossil Fuel Export and GDP Share of Countries in Europe and Central Asia and Sub-Saharan African, both Excluding High-Income, and Other Small States, Comprising 20% of the Global Population.

Source: Author's calculations from 2019 World Bank data: www.worldbank.org/indicator/ downloaded 10/28/2021. Fuel Exports are SITC Revision 3, "3. Mineral Fuel, Lubricants, and Related Materials". ECA countries (20) are: Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Georgia, Kazakhstan, Kosovo, Kyrgyz Republic, Moldova, Montenegro, North Macedonia, Romania, Russian Federation, Serbia, Tajikistan, Turkey, Turkmenistan, Ukraine, Uzbekistan. OSS countries (33) are: The Bahamas, Barbados, Antigua and Barbuda, Bhutan, Guinea-Bissau, Guyana, Iceland, Jamaica, Kiribati, Lesotho, Maldives, Malta, Marshall Islands, Mauritius, Federated State of Micronesia, Montenegro, Namibia, Nauru, Palau, Qatar, Samoa, San Marino, Sao Tome and Principe, Seychelles, Solomon Islands, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Timor-Leste, Tonga, Trinidad and Tobago, Tuvalu, Vanuatu. SSA countries (19) are: Angola, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe. Note: Guinea-Bissau (2019 Pop. 1.9 million) is included in both the OSS and SSA countries.

A similar analysis by country shown in Figure 3 below indicates that in 2019 1.1 billion people (14.2% of the roughly 7.7 billion global population) lived in countries for which liquid fossil fuel exports constitute over 10% of total exports, and these generated over $ 4 trillion of foreign exchange for these countries.

Fuel Exports Percent of Total Exports and Value (2019, Current $, By Country)							
Rank	Country Name	Fuel Exports % of Total Exports	Fuel Exports $ (millions)	Cumulative Fuel Exports $ (millions)	Pop (millions)	Cumulative Pop (millions)
1	Brunei Darussalam	82.2%	6,412.0	6,412	0.4	0.4
2	Kuwait	79.9%	898,052.9	904,465	4.2	4.6
3	Qatar	70.4%	64,774.0	969,239	2.8	7.5
4	Norway	54.3%	21,680.7	990,920	5.3	12.8
5	United Arab Emirates	50.8%	1,280,868.5	2,271,788	9.8	22.6
6	Russian Federation	45.3%	218,119.3	2,489,907	144.4	167.0
7	Kazakhstan	42.6%	1,332.1	2,491,239	18.5	185.5
8	Ecuador	35.1%	8,746.3	2,499,986	17.4	202.9
9	Mongolia	34.1%	2,135.5	2,502,121	3.2	206.1
10	Nigeria	31.7%	842.5	2,502,964	201.0	407.1
11	Malta	24.3%	349,875.3	2,852,839	0.5	407.6
12	Barbados	22.9%	929.6	2,853,769	0.3	407.9
13	Cyprus	20.7%	1,051.2	2,854,820	1.2	409.1
14	Indonesia	20.5%	13,365.7	2,868,186	270.6	679.7
15	Belarus	17.6%	8,142.2	2,876,328	9.4	689.1
16	Fiji	16.0%	1,367.7	2,877,695	0.9	690.0
17	Samoa	15.7%	99,321.6	2,977,017	0.2	690.2
18	Jamaica	15.3%	136,454.8	3,113,472	2.9	693.1
19	Australia	15.2%	51,294.1	3,164,766	25.4	718.5
20	Ghana	14.6%	12,017.4	3,176,783	30.4	748.9
21	Egypt, Arab Rep.	14.5%	7,680.4	3,184,464	100.4	849.3
22	Senegal	11.8%	77,796.1	3,262,260	16.3	865.6
23	Brazil	11.4%	30,313.6	3,292,573	211.0	1,076.7
24	Lithuania	11.2%	725,712.2	4,018,286	2.8	1,079.5
25	Malaysia	10.7%	402.2	4,018,688	31.9	1,111.4

Figure 3: Countries with Over 10% Liquid Fossil Fuel Export Shares (2019)

Source: Author's calculations from World Bank Indicators from www.worldbank.org/indicator/ downloaded 10/28/2021. Fuel Exports are SITC Revision 3, "3. Mineral Fuel, Lubricants, and Related Materials".[4]

[4] The Russian Federation, Nigeria, Malta, Barbados, Belarus, Ghana, and Senegal in Figure 3 are also included in one of the Figure 2 country groups.

II. How Can Short-Run Emergency Direct Cooling and Long-Run GHG Removal and Ecological Regeneration be Achieved?

A recent broad international coalition of leading climate scientists, policy experts, and activists, that includes the author, has recently formed and proposed an "all options must be on the table" climate strategy.[5] These were formulated in two letters sent to G20 and COP26 delegates. The latter also became a petition that was signed in short order by over 500 people.[6]

In it we asked that:

"COP26 adopt a resolution committing to develop a climate restoration plan no later than 2023 to limit global warming to well below 1° C. An effective and responsible plan will need to integrate three approaches:

1. Cooling the planet, particularly the polar regions and the Himalayas,
2. Reducing GHG emissions, including methane and other short-lived warming agents
3. Removing legacy CO2, methane, and other GHGs from the atmosphere."

Needless to say, HPAC has received no serious commitment or response from COP26 or the G20 to this proposal. None the less, we firmly believe that there is no other reasonable path forward for addressing the climate crisis.

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[5] Full disclosure: the author is a founding members of HPAC and serves on the HPAC Steering Circle.

[6] See https://www.healthyplanetaction.org/ and https://www.change.org/p/john-kerry-tell-world-leaders-at-cop26-to-unite-now-on-a-climate-restoration-action-plan?utm_content=cl_sharecopy_31171781_en-US%3A7&recruiter=2690263&utm_source=share_petition&utm_medium=copylink&utm_campaign=share_petition

Point 2, and now increasingly 3, have broad theoretical support in the climate science and policy making community, though that theoretical support has not translated into a robust political reality. But, per the discussion above, point 1 has little support, and with some notable and growing exceptions (National Academy of Sciences 2021), is generally viewed as off the table for mainstream climate discussion.

As Section I documents, we are now in a climate crisis. As discussed in Section II, we need to immediately apply direct cooling or climate triage (point 1 above) to limit the harm and suffering to humans and other species as we try to reduce and remove GHGs as quickly as possible to stabilize the climate.

a) The Florin Stratospheric Aerosol Injection (SAI) Implementation Framework

I believe that a recent white paper by Marie-Valentine Florin (2021) expresses a policy view that has a near future chance of broad acceptance. Florin addresses her remarks exclusively to SAI (Stratospheric Aerosol Injection – see below and Baiman (2021)) and points out that long term and extensive deployment of SAI carries with it physical and political risks. For the purposes of this paper I will not take issue with the widely held views of the potential physical risks of long-term SAI enumerated by Florin, though I believe that all are debatable and require further study, unlike the known and already present, calamitous risks of continued warming discussed in Section I.[7] I also will not address the potential "rogue actor" security risks, though as aerosols

[7] For example, there is now an extensive literature studying the possibility of carefully targeted SAI to achieve specific (beneficial) broad special and temporal levels of warming and precipitation (Lee et al 2020).

rapidly disperse in the stratosphere, it is not clear how a rogue actor would benefit or not be quickly shut down by international authorities backed by global powers.

Though Florin cites a number of possible SAI risks, her primary concern, and that of climate scientists and policy makers more generally, about SAI is that it:

- potentially be *too inexpensive,* as it is estimated at $3.6 billion for startup and $2.25 per year operational costs, or less by mimicking forest fire lofting
- And so *effective* at cooling the planet, as the 1991 Mount Pinatubo volcano is estimated to have lifted about 15 million tons of sulfur (as opposed to 3.3 million tons per year in the SAI estimate above) into the stratosphere and cooled the planet by 0.6 degrees Celsius for 15 months

that it would substantially reduce political pressure for long-run necessary global GHG mitigation and adaptation.

Given the enormous inertia in the way that current global governance is organized and operates, it is possible that successful SAI could make global political paralysis on GHG emissions and drawdown worse. But it is also possible that a successful global direct cooling effort would provide the motivation and hope for the implementation of a serious mandatory global emissions reduction and drawdown regime that, as argued below, is necessary for credible GHG drawdown.

Florin proposes a "shaving the peak" or "buying time" temporary role for SAI per Figure 4 below, that is based on an adaptation of the widely publicized plot by Long and Shepard (2014).[8]

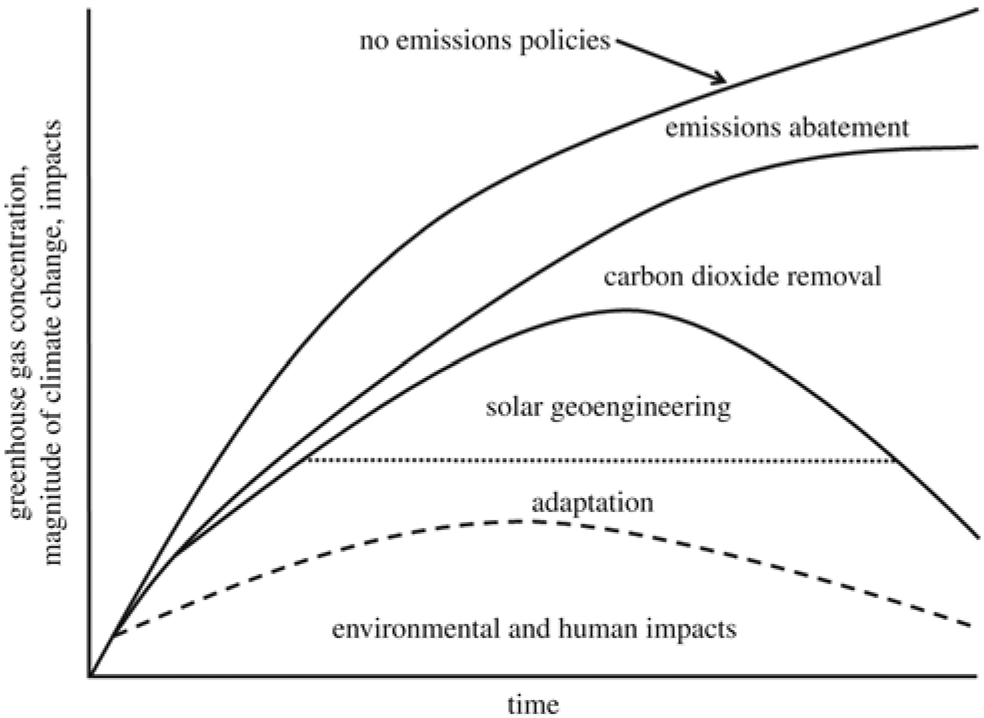

Figure 4: "Shaving the Peak" Implementation of Stratospheric Aerosol Injection Solar Geoengineering

Source: https://royalsocietypublishing.org/doi/10.1098/rspa.2019.0255 **(**Reynolds, 2019, Figure 3). Original by Jane Long and John Shepherd: The strategic value of geoengineering research**.**

[8] https://link.springer.com/referenceworkentry/10.1007%2F978-94-007-5784-4_24

She proposes a non-emergency risk management decision framework for temporary deployment of SAI that specifies SAI should unless a credible global drawdown plan is being implemented so that a clear date for ending SAI without abrupt warming can be specified.

I understand the thinking behind the Florin proposal and applaud the effort to devise a workable strategy that may allow SAI to be seriously considered in dominant climate policy circles. By sequencing the start of SAI direct cooling after a credible GHG emissions reduction plan, and SAI cessation after a credible GHG drawdown plan, Florin's proposal goes some way toward acknowledging and responding to the two climate crises that we are facing.

Unfortunately, however, I believe that even the Florin plan may not be adequate as we may need emergency cooling now, and we may need SAI before a credible global GHG emissions reduction and removal plan, that will require a binding international cap and trade agreement, can be implemented.

b) SAI is not the only form of climate triage or direct cooling, and local direct cooling methods are urgently needed now

Many different cooling methods have been proposed with very different local, regional, and global, ranges of potential impacts. All be carefully studied, piloted, and, if believed to be successful and safe, very gradually implemented pending the outcomes of continuous assessment.

Second, the evaluation of risks of these methods should always be in the context of the certainty of increasing climate catastrophe if we are unable to cool the planet, and particularly the poles.

Third, reducing global warming may be one of the most important immediate things that we can do for global climate equity, as estimates discussed in Section I suggest that a disproportionate share of near term harm from climate catastrophe will be borne by the most disadvantaged countries, and individuals within countries.

The claim, therefore, without evidence or study, that the risks of attempting to cool, regardless of method attempted, will always be greater that the risk of doing nothing to save the Arctic sea ice, and reduce or reverse the certainty of increasing climate catastrophe (that will occur as long as the stock of GHGs in the atmosphere is increasing) cannot be justified, as such inaction could cause immeasurable, and potentially avoidable, increased human and species suffering.

To the contrary, just listing some of the cooling methods that have been proposed, shows that the range of possible impacts, with some relatively confined, to others with greater scope for unanticipated adverse impacts, is very large, so that these impacts cannot be peremptorily dismissed as unacceptable, particularly when compared with the risks of not doing anything.

Some of the proposed methods are: Marine Cloud Brightening (MCB), Mirrors for Earth's Energy Rebalancing, Wind driven sea water pumps, Surface Albedo Modification (formerly Floating Sand), Iron Salt Aerosol, Stratospheric Aerosol Injection (SAI), Floating Sand, and Cirrus Cloud Thinning (CCN), see Baiman 2021, p. 615-616). Mirrors for Earth's Energy Rebalancing (MEER) would offer local and regional cooling solutions based on deployment of arrays of mirrors on the earth's surface[9], and wind driven sea water pumps could increase Arctic winter ice formation, slowing summer ice melt and methane release (Desch et 2017).

c) Mandatory global cap and trade regimes are necessary to achieve credible GHG drawdown

It is widely recognized that the politics of climate change are currently paralyzed. We can't have credible GHG reduction and removal without a sustainable (REME) economic transition in developing countries. But developing countries cannot afford to do this without massive financial and technological help that equalizes life opportunities across the globe going forward. The only way to achieve this is through a binding global cap and trade system that would induce a mandatory flow of funding and technology for both emissions and withdrawal from rich to poor countries (Chichilnisky and Bal, 2019).

Moral suasion and Paris Accord voluntary "Nationally Determined Commitments" (NDCs) are unrealistic and unworkable paths for rapid global GHG emissions reduction and drawdown in the next few decades. The binding global cap and trade induced Kyoto "Clean Development Mechanism" (CDM) transferred $ 303.8 billion from rich countries to poor countries for mitigation and adaptation (United Nations Climate Change 2018).[10] In contrast the Paris Accord voluntary Green Climate Fund (GCF) had over the period 2014-2021 (as of 9/2021) has

[9] https://www.meerreflection.com/home

[10] According to this 2001-2018 UNFCCC report, the CDM led to the investment of $ 303.8 billion in climate and sustainable development projects that resulted in an almost 2 GT CO2eq emissions reduction in the developing world.

raised only $16.8 billion.[11] An alternative would be for the US to simply create the global currency (US dollars) necessary to fund a climate transition, but this appears less politically feasible than an enhanced Kyoto-like global cap and trade regime, a version of which has been implemented but then (very unfortunately!) allowed to lapse in 2015 (Baiman, 2020).

The European Union (EU) was the only major region of the world that continued to internally enforce a Kyoto-like cap and trade internal Emissions Trading System (ETS) after the global mandatory Kyoto accord was replaced in 2015 by the voluntary Paris Climate Agreement. The EU ETS, with individual country carbon taxes on sectors not yet covered by it, has been the only major region of the world to significantly cut, by 24% from 1990 to 2019, its GHG emissions since 1990.[12] In contrast, US GHG emissions increased by 2% over this period.[13] The 1990-2020 the population of the EU grew 20.4% more slowly than that of the US14, but from 1997 (earliest available data) to 2019 the real value of manufacturing output (value-added) of the EU grew only 7.3% more slowly than that of the US15, suggesting that neither factor can fully account for the 26% greater decline in EU GHG emissions relative to the US.16 During this period both regions outsourced manufacturing, particularly to China.

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[11]$7.2 billion during the 2014 Initial Resource Mobilization (IRM) and as of Sep. 2021 another $ 9.6 billion during the first replenishment (GCF-1) 2020-2023 period, see: https://www.greenclimate.fund/about/resource-mobilisation/irm

[12] https://ec.europa.eu/clima/eu-action/climate-strategies-targets/progress-made-cutting-emissions/kyoto-2nd-commitment-period-2013-20_en

[13] https://www.epa.gov/climat-indicators/climate-change-indicators-us-greenhouse-gas-emissions

[14] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Population_and_population_change_statistics and https://data.worldbank.org/indicator/SP.POP.TOTL?locations=US&view=chart

[15] World Bank NV.IND.MANF.KD series, downloaded 2/1/2022.

[16] GDP growth, as opposed to manufacturing growth, is less likely to be correlated to GHG emissions, as particularly in the US, this was disproportionally in the lower GHG emitting service sector. For example, "Financial Intermediation Services Indirectly Measured (FISM), newly added to GDP accounting before 2008, and an

Carbon pricing mechanisms now apply to about a fifth of global GHG emissions (World Bank Group 2020), and the EU may impose a "Carbon Border Adjustment Mechanism" could increase their coverage.[17] However, per Figures 2-3, and the discussion above, it appears that a *global* ETS that generates enforceable transfers of investment from rich to poor countries is necessary to a achieve global GHG reduction and removal.[18]

However, the proposed EU Carbon Border Adjustment Mechanism is a reminder that serious efforts to transform the global economy require mandatory and enforceable rules like that of the WTO. In my view the free trade doctrine is fundamentally erroneous and economically harmful, but regardless of its merits, I don't think any serious proponent would suggest that it could be *voluntarily* implemented (Baiman, 2017). How can we expect a more radical and fundamental transformation of the global economy to a REME to be achieved through voluntary Paris Accord NDCs and GCF philanthropy?

A global mandatory net carbon "dumping fee" or "cap and trade" market for GHGs with a cap that very rapidly goes to zero, based on responsibility and capacity, and enforced by national governments should be established.[19] A revived global Emissions Trading System would increase the efficiency and scope of drawing down GHGs and lead to a large transfer of funding and investment to developing countries, as occurred under the Clean Development Mechanism

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increasingly important part of US GDP in particular, is arguably fictitious output that does reflect increased economic activity (Mazucato 2018, Chap. 3) (Baiman, 2014).

[17] https://ec.europa.eu/taxation_customs/green-taxation-0/carbon-border-adjustment-mechanism_en

[18] https://ec.europa.eu/taxation_customs/green-taxation-0/carbon-border-adjustment-mechanism_en

[19] As proposed for example by the Greenhouse Development Rights Framework: http://gdrights.org/about/

(CDM) of the Kyoto Protocol, and would address the regulation and governance issues raised by critics (Chichilnisky and Bal 2019; Hahnel 2012). Hahnel points out that as national GHG emissions can be more accurately estimated than those of many specific transactions, individual countries can be held responsible for their emissions regardless of whether traded GHG offsets are real or not – an issue that is less likely to be a problem for carbon capture than for, especially natural, GHG mitigation.[20] An additional, or alternative, global cap and trade market for produced CO2 extracted from the atmosphere or ocean, and a "Clean Investment Mechanism" to support investment in this "Negative Emissions Technology" in developing countries, analogous to the Kyoto CDM, has recently been suggested.[21] A Clean Investment Mechanism would foster profitable investment in Negative Emissions Technology in developing and developed countries to achieve carbon capture goals and comply with the1997 Byrd Hagel law stipulating that any US climate response grow the economy. If the Clean Investment Mechanism included social floor regulations, such as wages, working conditions, and corporate income taxes, it could serve to leverage capitalist incentives to rapidly scale up production of CDR, a public good, and raise living standards in developing countries (Baiman 2017: 135–63).

IV. Conclusion

We are facing both a short-term emergency cooling crisis and a long-term GHG drawdown planetary ecological crisis. We must address both. The first requires emergency direct cooling,

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[20] For example, California's cap and trade law carbon dioxide compliance offset protocols (Urban forest, and US forest) apply exclusively to natural mitigation: https://ww2.arb.ca.gov/our-work/programs/compliance-offset-program .

[21] As suggested by Graciela Chichilnisky in a working document of the Elk Coast Institute DAC Climate Mobilization Summit in 2021.

or temporary “triage” or a “tourniquet, for our bleeding planet”. The second requires rapid GHG emissions reductions and drawdown and natural planetary regeneration that realistically will take at least a few decades and may take a century or more. Conflating the challenge and opportunity of the second crisis with a response to the first crisis will not produce a rapid and credible global response to the second crisis because of structural economic inequity and fossil fuel dependency that is deeply embedded in the current global economy. Realistically, we need emergency direct cooling to address the first crisis and a long-term binding global cap and trade “emissions trading system” (ETS) to address the second. The Florin proposal that conditions SAI direct cooling on credible GHG emissions and drawdown is a step in the right direction, but omits other direct cooling methods and effectively makes the deployment of SAI contingent on a global ETS that may not be possible before the deployment of SAI becomes necessary. Rather than conflating our two climate crises, or conditioning the solution of the first on a solution to the second, we need to address both on an emergency basis by putting all options on the table as called for in the HPAC proposal.

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