Whose climate intervention? Solar geoengineering, fractions of capital, and hegemonic strategy

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Abstract

Proposals for slowing climate change by reflecting sunlight back to space, known as solar geoengineering (SG), are gaining traction in climate policy. Given SG's capacity to slow warming without reducing carbon emissions, prominent criticism suggests that it will enable fossil fueled business-as-usual. This assessment is not without merit, yet the primary funders of SG research do not emanate from fossil capital. We analyze sources of funding for SG research, finding close ties to financial and technological capital as well as a number of billionaire philanthropists. These corporate sectors and associated philanthropies comprise part of "climate capital" – the fraction of the capitalist class aligned with climate action. We argue that SG is being positioned as a tactic for enabling incremental, market-driven decarbonization, explore key institutions advocating this approach in US climate policy, and conclude that SG is poised to serve as a tool for class compromise between fossil and climate capital.

Introduction

As the climate crisis bears down on communities and ecosystems across the planet, and concerted political action remains inadequate, proposals for extreme technological interventions into the climate system are gaining traction in climate policy. One such intervention is solar geoengineering (SG), proposed technologies that could potentially cool the planet by modifying Earth's albedo. SG proposals include brightening clouds over the ocean, increasing Arctic reflectivity by spreading glass microspheres across the ice, or continually spraying aerosols into the lower stratosphere to block a fraction of solar radiation from entering Earth's atmosphere. The latter approach, referred to as Stratospheric Aerosol Injection (SAI), is the leading SG proposal owing to the fact that it is likely cheap, fast-acting, and operative at the planetary scale (Smith and Wagner 2018), with current research examining ways to fine-tune SAI to achieve desired effects while minimizing adverse impacts (e.g. Irvine et al. 2019; Keith & MacMartin 2015). Given these characteristics, a range of governments have supported SG research since 2008, including Australia, China, India, Germany, the UK, and the United States.

The U.S. currently dominates the SG field through private philanthropic funding of academic research programs, with growing interest and investment from government agencies. Over the last several years, a number of key institutions, events, and reports have pushed SG onto the climate policy agenda in the U.S., including: two high-profile reports on "climate intervention" by the

National Research Council (2015) and the National Academies of Science, Engineering and Medicine (2021); the launch of the Harvard Solar Geoengineering Research Program (HSGRP) in 2017; HSGRP's advancement of SCoPEX, the first outdoor field-test of SAI technology; Congressional appropriation of \$4 million to National Oceanic and Atmospheric Administration (NOAA) to fund SG research; interest in the technology from the defense and intelligence community (see Surprise 2020a); backing from billionaires like Bill Gates; and cautious embrace of research by NGO's such as the Environmental Defense Fund, Resources for the Future, and the Union of Concerned Scientists.

The coalescence of climate scientists, government agencies, environmental NGOs, and billionaire philanthropists into an SG policy network is a recent development. Early political interest in SG in the U.S. emanated largely from conservative, climate denying think tanks and politicians backed by the fossil fuel industry. For example, early discussions were initiated by Pentagon-linked physicists at the Lawrence Livermore National Laboratory and the conservative Hoover Institute who argued for SG as a means to avoid the economic costs of mitigation (Teller, Wood, and Hyde 1996). These studies spurred meetings on the topic early in the Bush Administration (Popular Science 2005), and more concerted efforts between 2007-2010. Against a backdrop that included the 2007 Intergovernmental Panel on Climate Change report, the acclaim of Al Gore's *An Inconvenient Truth*, the election of Barack Obama, and the 2009 American Climate and Energy Security Act followed by the Copenhagen Climate Accord, conservative forces sought to develop a position on climate change that would still enable unrestrained fossil fuel production. SG – given its capacity to reduce temperature independent of carbon emissions – fit exceedingly well in this agenda. Thus, conservative think tanks like the American Enterprise Institute and the Heartland Institute wrote reports and convened conferences on SG research (Bickel and Lane 2009; see also Collomb 2019; Hamilton 2013). The first congressional hearings on the subject were held in 2010 by a Republican-controlled House Committee on Science, Space, and Technology under the leadership of fossil fuel-funded climate denier Lamar Smith, and representatives from ExxonMobil (e.g. Haroon Keshegi), British Petroleum (e.g. Steve Koonin) were involved in early SG meetings or reports.

Interest from these quarters fanned the flames of critics who argued that geoengineering technologies would merely allow fossil fueled business-as-usual to continue unimpeded, and enable the avoidance or deterrence of necessary mitigation efforts (ETC Group 2010; Hamilton 2013; Robock et al. 2008). Yet, as we show below, fossil fuel interests and climate denial organizations are now largely absent from SG policy-planning, while prominent criticism of the technology continues to link it to the fossil fuel industry (ETC Group 2017; Fuhr & Schneider 2020; Muffet & Feit 2019). These critiques are well founded, as SAI directly serves the interests of the fossil fuel industry in its promise to extend fossil capitalism (Gunderson et al. 2019; Markusson et al. 2020). However, they tend to overlook many of the more subtle ways the technology has advanced and is now promoted by climate scientists, environmental NGOs, “green” philanthropists, and Silicon Valley ecomodernists – the “climate capitalist” policy network (Newell and Paterson 2010; Sapinski 2015; 2016). To effectively understand the

advancement of SG as a tool of *climate capitalism*, we need a clearer analysis of this realignment.

We explore the shift in support for SG research, experimentation, and potential deployment from interests aligned with fossil capital (the fossil fuel industry) to climate capital (corporate power aligned with climate action) in three sections. **First**, we examine SG funding organizations in the U.S., mapping flows of funding from philanthropic foundations, wealthy individuals and government agencies to current SG research projects.¹ We focus on connections among the boards of directors of leading U.S.-based SG research funders and the corporate community, finding close ties to technology and financial corporations that comprise key segments of climate capital, as well as a preponderance of billionaires, billionaire-founded philanthropies, and wealthy individuals funding SG research with ties to these economic sectors.

Second, we situate the turn to SG on the part of climate capital in the contradiction between capitalism as a system of endless accumulation and planetary sustainability. The primary response to this contradiction has been market-driven “green” capitalism, the emergence of which is generating a crisis within the capitalist power bloc driven by the divergent interests of fossil and climate capital. We argue that market-driven climate capitalism is incapable of decarbonization on relevant timescales, and that state intervention into the market to effectuate the transition is structurally limited by the precepts of capitalist political economy. In this context, SG becomes a form of state intervention to manage that climate crisis in which the climate system – rather than the economy – becomes the primary target of intervention. **Third**, we assess the connections between climate capitalism, SG research, and state intervention by exploring the emergent “common sense” around inclusion of SG as a central dimension of *current* climate policy, examining specific proposals from leading corporate think tanks (The Aspen Institute and Resources for the Future). From there we turn to key ideologies stitching together these coalitions - philanthrocapitalism and ecomodernsim - and outline emerging interest in SG within the Biden Administration.

This material and ideological shift in support for SG corresponds to the decline of fossil capital and the rise of technology capital (both mediated by financial capital) as hegemonic within the capitalist power bloc, and renders SG palatable to the U.S. state, specifically centrist, technocratic, climate-conscious members of the Democratic Party. SG is being positioned as a tool that can both enable incremental, market-driven climate policy that appeals to climate capital *and* delay impending devaluations of fossil capital (in which financial capital is heavily invested, see Fichtner et al. 2017; Carroll & Huijzer 2021). In other words, it can act as a tactic for forging class compromise in climate policy. We conceptualize it as a form of state intervention into the climate crisis not on behalf of one fraction of capital, but to maintain the possibility of accumulation in the face of climate crisis, and ensure the hegemony of capital against the rise of radical climate justice movements. Thus, despite the emergent “green” or “progressive” discourse surrounding SG, it remains rooted in the very same conservative, reactionary logics and impulses that initially attracted climate denialists: it is a way to deny,

delay, and obstruct the reality of what climate change means for the continued reproduction of capitalism.

Section I - *Buying time*: The funding of solar geoengineering research

[Philanthropies] serve as ‘cooling-out’ agencies, delaying and preventing more radical, structural change. They help maintain an economic and political order, international in scope, which benefits the ruling class interests of philanthropists (Arnove 1980)

We begin by exploring the funding of SG research in the U.S., focusing on sources of funding, corporate ties, and the wealth of individual philanthropists. The best available compilation of SG funding data to date comes from Necheles et al. (2019), who track total, global funding for research from 2008 – 2018. Based on their collection, total funding for SG research remained relatively low over the 2008 – 2018 period, with governments (primarily in Europe) spending \$31.3 million on research, and private funding (primarily in the US) reaching approximately \$20 million in this time frame (although this has grown in the last two years with the expansion of HSGRP, new federal funding, and recent grants from the NGO SilverLining). Early funding (2008 – 2016) was predominantly concentrated in Europe, primarily the EU, Germany, and the UK, with these respective governments financing much of the research.

Beginning in 2016, there was a marked shift in the geographical center of research, with the U.S. now dominating the field, and a proliferation of funding from private, philanthropic, and venture capital sources (Figure 1). This constitutes a shift not just internationally, but within the U.S. SG landscape as well. Whereas early political interest in SG emanated from climate-denying think tanks and politicians backed by the fossil fuel industry, recent funding and support derives from foundations and individuals with ties to technology and financial firms, many of which have a demonstrated record of environmental philanthropy.

Figure 1 maps funding flows covering the period 2018-2020. It shows that recent state funding in the U.S. comes from the National Science Foundation (NSF) supporting modeling projects at major universities (SCRiM at Penn State, GeoMIP at Rutgers and at Cornell). In contrast, private funding comes from a variety of philanthropic foundations (diamond shapes on Figure 1), private firms (hourglass shapes) and wealthy individuals (squares with cross). Two funders occupy central positions in the network, each funding no less than five SG projects: The Open Philanthropy Project, founded by Facebook billionaire Dustin Moskowitz, his wife Cari Tuna, and former hedge fund trader Holden Karnofsky, and SilverLining, closely tied to Silicon Valley venture capital (VC). Bill Gates, of Microsoft fame, is another key player in the field, funding three projects either directly or through his Fund for Innovative Climate and Energy Research (FICER). Philanthropic funding for SG in the U.S. revolves around a core group of seven organizations that have funded two or more SG research projects in recent years. Table 1 lists these organizations, their key corporate connections, and SG initiatives they fund.

Figure 1. The global network of SG funding

Color key: Blue = United States, Red = Canada, Orange = United Kingdom, Green = Germany, Yellow = India, Pink = China, White = undetermined.

Shapes key: Circle = SG research project, Diamond = philanthropic foundation, Up triangle = private firm, Down triangle = think tank, Hourglass = NGO or university research center, Square = state, Box = individual.

Shape size: Number of projects funded.

Sources: Necheles et al. (2019) and authors' data.

To understand the alignment of these organizations with various fractions of capital, we trace board-level interlocks with the corporate community – governance-level connections formed when corporate directors sit on the boards of multiple organizations (Domhoff 2014). In its capacity to decide the strategic orientations of a foundation's distribution of funding, the board of directors exerts allocative power on behalf of philanthropic capital. Data about board members' interlocks to different economic sectors thus show which sector(s) of the economy SG funders are most closely embedded. As shown in Table 2, among the 91 directors of the top seven SG funders, we count a total of 62 corporate interlocks. The breakdown of these connections to the corporate world shows a total shift in the affiliation of SG supporters: the financial sector comprises 38.7% of the links, the commercial and services sector 24.2% and the high-tech sector 19.4%. Among all corporations, 20 interlocks (32.3%) are to high tech related firms, including financial or consulting firms providing services specifically to the high tech sector. On the other hand, a mere five interlocks (8.1%) connect SG funders to fossil fuel extractive firms and to carbon-linked sectors such as aviation, car-making, steel production and chemical manufacturing (Table 2).

Table 1. Leading private funders of SG

Funding organization	Description/background	SG initiatives funded ^a
Open Philanthropy Project	Founded by Dustin Moskovitz (billionaire co-founder of Facebook) with partner Cari Tuna, and Holden Karnofsky, formerly of hedge fund Bridgewater Associates. Board includes Divesh Mahkan, founder of ICONIQ Capital, formerly of Goldman Sachs and Morgan Stanley	<ul style="list-style-type: none"> • Forum on Climate Engineering Assessment (FCEA) • HSGRP (\$4.5M 2016-17) • Solar Radiation Management Governance Initiative (SRMGI) DECIMALS Fund • UCLA Emmett Institute • Total amount: \$5.76M
SilverLining	Funded by venture capital firms LowerCarbon Capital and First Round Capital; staff and board include former executives from Goldman Sachs and JPMorgan Chase Co.	<ul style="list-style-type: none"> • GLENS (NCAR) • Marine Cloud Brightening Project (MCB) • Cornell Climate Engineering • GeoMIP • SRMGI • Total amount: \$3M
Bill Gates/ FICER	FICER is Bill Gates' personal fund for energy and geoengineering research, administered by geoengineering researchers Ken Caldeira and David Keith	<ul style="list-style-type: none"> • HSGRP (\$7.65M 2013-18) • MCB (\$150K) • SRMGI (\$100K)
Environmental Defense Fund(EDF)	Environmental NGO, many corporate ties on board; corporate partnerships e.g. Citigroup, GE, McDonalds, Shell, Tyson, Walmart	<ul style="list-style-type: none"> • Cornell Climate Engineering • SRMGI
Pritzker Innovation Fund	Rachel Pritzker, an heir to the multi-billionaire Pritzker family, founders of the Hyatt Hotels Corporation	<ul style="list-style-type: none"> • HSGRP • SilverLining
VK Rasmussen Foundation	Family foundation founded by Swedish inventor/businessmanVillum Kann Rasmussen; funds range of environmental groups, some opposed to geoengineering; raises funds from investment capital	<ul style="list-style-type: none"> • Carnegie Climate Governance Initiative (C2G) (\$5.55M) • FCEA • National Academies
Alfred P. Sloan Foundation	Founded by Alfred P. Sloan of General Motors; claims \$1.9 billion in assets; raises funds from investment capital	<ul style="list-style-type: none"> • HSGRP (\$90K) • CSPO Arizona State University (\$300K)

^a Amounts indicated when available.

Sources: Necheles et al. (2019) and authors' data.

Table 2. Board-level interlocks between top SG funders and different economic sectors

Economic sector	N	%
Finance, investment and real estate	24	38.7%
Commercial, advisory and misc services	15	24.2%
Technology, equipment, software, communications	12	19.4%
Other industrial, mediated relation to fossil fuels	6	9.7%
Carbon-linked industrial	4	6.5%
Carbon extraction, processing, distribution	1	1.6%
Total	62	100.0%

Sources: Necheles et al. (2019) and authors' data.

As an illustration, SilverLining's board includes Rachel Pritzker, Clay Dumas of venture capital firm Lowercarbon Capital, and Steve Strongin, former Head of Global Investment Research and Chair of the Global Markets Institute at Goldman Sachs. SilverLining's "safe climate research initiative," which distributed \$3 million to five research programs, is funded by: billionaire Chris Sacca's Lowercarbon Capital; Matt Cohler, a former Vice President of Facebook, partner at Benchmark (a Silicon Valley VC firm), and board member of Asana (founded by OPP's Dustin Moskovitz); Bill Trenchard, partner at First Round Capital (Silicon Valley VC firm); the LAD Climate Fund; and the Pritzker Innovation Fund.

Another key feature of SG funding in the U.S. is the number of billionaires and billionaire-founded philanthropies involved in the field. As shown in Table 3, a large part of these individuals' wealth comes from top high-tech firms including Microsoft, Hewlett-Packard, Google and Skype; only one of 11 billionaires acquired his fortune through the carbon extractive sector, former Enron trader John Arnold.

In addition to the billionaires listed in Table 3, several high net-worth individuals also fund SG research. For example, key funders of HSGRP include: G. Leonard Baker, Jr., partner at Sutter Hill Ventures (Silicon Valley VC firm); Howard Fischer, founder of Basso Capital Management; Ross Garon of Millennium Capital; The Tansy Foundation, founded by Eric Wepsic, an executive at hedge fund D. E. Shaw; and Teza Technologies, founded by Misha Malyshev, formerly of hedge fund Citadel Investment Group and McKinsey & Co, among others.

SG funding is thus comprised of a core group of organizations and individuals with multiple ties to corporate power via their boards of directors, primarily in the financial and technology capital sectors. Among this group, we find at least 11 billionaires or billionaire-founded philanthropies, and a slew of wealthy individuals with direct ties to venture capital firms and billionaire-led hedge funds. SG research funding is the province of the financial and high tech fractions of the capitalist class, not the fossil fuel fraction. We explicate these shifting alignments in the next section, exploring the relationships between capitalism and climate, fractions of capital, and state interventions in ecological-economic crises.

Table 3. Billionaire funders of SG

Billionaire funder	Background/description	Economic sector	Foundation or venture	SG initiatives funded
John Arnold	Billionaire investor, formerly of Enron and energy investment firm Centaurus Advisors	Carbon extraction	John and Laura Arnold Foundation (restructured as Arnold Ventures LLC in 2019)	HSGRP
Julian C. Baker	Billionaire manager of Baker Brothers Advisors hedge fund	Finance	J. Baker Foundation	HSGRP
Caspersen family	Family of Wall Street billionaires	Finance	O.W. Caspersen Foundation	HSGRP
Bill Gates	Founder of Microsoft; current net worth: \$129 billion	Technology		<ul style="list-style-type: none"> • FICER • HSGRP • SRMGI • MCB
William Hewlett	Founder of Hewlett-Packard	Technology	Hewlett Foundation	HSGRP
Alan Parker	Formerly of DFS Group, a subsidiary of LVMH (Louis Vuitton)	Commercial	OAK Foundation	C2G
Dustin Moskovitz and Cari Tuna	Founder of Facebook and his wife	Technology	Open Philanthropy Project	<ul style="list-style-type: none"> • FCEA • HSGRP • SRMGI • UCLA Emmett Institute
Rachel Pritzker	Heir to the Pritzker family fortune (Hyatt Hotels)	Commercial	Pritzker Innovation Fund	<ul style="list-style-type: none"> • HSGRP • SilverLining
Chris and Crystal Sacca	Venture capitalist, former lawyer for Google, and founder of Lowercarbon Capital with his wife	Technology	Lowercarbon Capital	<ul style="list-style-type: none"> • HSGRP • SilverLining
David Vogel and Thais Lopez Vogel	Founder of hedge fund Voloridge Investment Management	Finance	Volo Foundation	HSGRP
Niklas Zennström	Founder of Skype	Technology	Zennström Philanthropies	SRMGI

Sources: Necheles et al. (2019) and authors' data.

Section II – The capitalist climate crisis, fractions of capital, and SG as state intervention

The turn to SG by climate capital and capitalist states is deeply rooted in the fundamental contradiction between capitalism as a system of endless accumulation – predicated on expropriation, exploitation, and constant expansion via competition – and sustainable socio-environmental relations. In this section we provide theoretical contextualization for the shifting political economy of SG by examining the threat climate change poses to the hegemony of capital, capital's primary reaction to this threat, and the intrinsically truncated ability for capital and capitalist states to manage systemic ecological-economic crises like climate change.

Many scholars have analyzed the contradictions that emerge from capital's drive for endless accumulation and the biophysical systems on which accumulation depends: from the planetary-scale destructive properties of capitalist expansion (Foster, Clark, and York 2011), to the ways in which environmental degradation and pollution threaten the reproduction of capital itself (Moore 2015; O'Connor 1988). To date, capital has responded to these contradictions with a project of "green" or climate capitalism: processes through which capitalist actors seek to simultaneously manage and profit from ecological crises via carbon pricing, ecosystem services, privatized conservation, renewable energy investment/subsidies, carbon capture technologies, green consumerism, and so on that do not fundamentally alter capitalist growth dynamics or forms of class domination (Brand 2016; Dempsey 2016; Fairhead et al. 2012; Knuth 2018; Sapinski 2015). This private, competitive, market-driven approach is unlikely to manage the most severe risks of the climate crisis on necessary timescales.²

It cannot, therefore, prevent the most fundamental threats posed by the climate crisis *even to capital itself*. These include the trillions in losses in stranded fossil fuel assets under strong climate policy (Mercure et al. 2018), the value of coastal infrastructure (Kirezci et al. 2020) and financial assets (Dietz et al. 2016), decreases in agricultural productivity (Ray et al. 2019), and the near-term investment costs of large-scale energy transitions (Semieniuk et al. 2021), all adding up to potentially severe losses in global GDP – 18% by 2050 according to some estimates (Swiss Re Institute 2021). For a system predicated on constant growth, expansion, and accumulation, losses at this scale – and the political instability they would generate – would be systemically risky if not fatal (hence the World Economic Forum considers climate change the top economic threat, Edmond 2020).

When faced with ecological-economic crises like climate change, capital has historically been unable to act in its collective class-interest; its responses to such crises are always dependent on active state intervention (O'Connor 1988). O'Connor's "second contradiction" thesis argues that capital cannot merely continue to produce newly commodified natures as substitutes or continue to accumulate in the midst of ecological breakdown, nor will such crises inexorably generate the end of capitalism. Rather, as capitalism produces limits to its own expansion and survival, the *capitalist state* increasingly mediates and manages the capital-nature relation. For O'Connor (1998, 137), ecological crisis is "as much (or more) a political and ideological category as it is a scientific construct." That is, although specifically-capitalist ecological crises emerge through costs incurred

via biophysical degradation, the key struggles revolve around whether and how the capitalist state recognizes and defines the scope of the crisis and is compelled (or not) to marshal powers of regulatory, financial, or technological crisis management.

The broad dynamics of state intervention in moments of capitalist crisis can be fleshed out through Nicos Poulantzas' discussion of the relationship between the capitalist state, hegemony, and the power bloc. For Poulantzas, the capitalist state "organizes the long term political interests of a *power bloc*, which is composed of several bourgeois class fractions ..." (2000, 127, original emphasis). Poulantzas argues that monopoly capital – large-scale, multinational corporations that dominate key sectors of the economy – is hegemonic, but divided by competitive, sectoral interests: e.g. financial capital, landowning capital, industrial capital. Thus, while the capitalist class can and does organize nationally and transnationally (Carroll 2010; Domhoff 2014), it is nonetheless riven by contradictions stemming from the different accumulation requirements of the various fractions of capital.

As Poulantzas notes, the power bloc "constitutes a *contradictory unity* of dominant classes or fractions, a unity dominated by the hegemonic class or fraction ... Left to themselves the classes and fractions at the level of political domination are not only exhausted by internal conflicts but, more often than not, founder in contradictions which make them incapable of governing politically" (1973, 297-8, original emphasis). Hence the capitalist state is not a direct instrument of the capitalist class but a social relation, the "material condensation of a relationship of forces among classes and class fractions," wherein it holds a degree of relative autonomy from the dominant class, allowing it to "represent the long-term political interests of the whole bourgeoisie" (2000, 128). The capitalist state organizes crisis-interventions not directly on the behalf of any particular fraction of capital, but to manage conflicts in capitalist societies that ultimately maintain the hegemony of capitalist social relations.

The era of climate crisis requires an understanding of the relationship between the state, capitalist fractions, and intervention that moves beyond narrow conceptions of economic sectors to include issues of societal consequence that represent opposing interests among fractions within the power bloc (Robinson and Harris 2000; Ougaard 2016). A number of recent analyses identify a split in the power bloc centering on fossil capital and sectors more aligned with technology capital and inclined to climate action (climate capital). For example, capital was divided on U.S. imperial strategy under the Bush Administration. The "nationalist" fraction of transnational U.S.-based capital, comprised of the fossil fuel and defense industries and closely linked to the U.S. state was in favor of unilateral militarism in the Middle East, whereas the "globalist" fraction, composed of corporations from finance, tech, and beyond were largely concerned with the war's impact on the global economy and the deterioration of open multilateralism (Beiler and Morton 2015). This split is now increasingly driven by climate change, as the cheapness of renewable energy and the financial costs of climate change are tilting power against fossil capital and towards industries attempting to profit from climate crisis (Ougaard 2016). Hence climate capital is growing increasingly influential within the power bloc (Newell and Patterson 2010; Sapinski 2015, 2016).

Yet the hegemony of climate capital is far from solidified, as financial capital remains heavily invested in the fossil fuel industry (Carroll and Huijzer 2021; Fichtner et al. 2017). This impasse leads some to see an emergent conflict within the power bloc among “inclusive capitalism” (neoliberalism and cultural openness with some Keynesian reforms), militarized accumulation (the merging of authoritarian regimes with fossil, defense, and surveillance capital as profit centers), or sustainable capitalism in the form of a China-led Green New Deal (Harris 2019). Others wager that capital’s response to climate change augurs two conflicting political responses: Climate Leviathan, a green-Keynesian capitalist alliance enacted via the scaling up of sovereign power to the planetary level, and Climate Behemoth, a coalition defined by fossil capitalism, nationalism, authoritarianism, and militarization (Wainwright and Mann 2018). Similarly, Carroll (2020) emphasizes that climate capitalism aims to generate a passive revolution and instantiate a “green” regime of accumulation as a compromise between fossil capital at one end of the spectrum, and the progressive project of energy democracy at the other (see also Brand 2016; Sapinski 2016; Surprise 2018; 2020b).

These potential configurations are speculative, but rooted in concrete shifts in capitalist power. In terms of market capitalization, technology capital is the leading sector in the power bloc, and this sector has taken the most aggressive stances on climate action and carbon-negative pledges (e.g. Microsoft and Facebook). Hence Bichler and Nitzan (2017) argue that the hegemonic coalition of global capitalism, what they term the Weapondollar-Petrodollar coalition – defined by the relationship between oil, the dollar, weapons sales, and U.S. imperialism – is being eclipsed by the “ascent of a global ‘Technodollar Coalition’” after 2016 (Figure 2). The Technodollar coalition is a “constellation of capitalist interests concentrated primarily in information, communication, automation, and biotechnology whose members are highly averse to oil crises, stagflation, and regime change – the very processes that make the Weapondollar-Petrodollar coalition tick.” The Technodollar coalition is on the ascent in part because of U.S. hegemonic decline and the inability of the U.S. military to continue to control energy conflicts, and the growing realization that climate change is driving economies to reduce their reliance on fossil fuels.

Drawing on this analysis of the capital-climate contradiction, the power bloc, and fractions of capital, we argue that the shift in political-economic alignments around SG from fossil capital to climate capital turn on three factors: (1) the rise of the Technodollar Coalition (broadly consonant with climate capital) puts this fraction in a dominant position within the power bloc, where it amasses excess capital to funnel into philanthropic ventures shaping the development of planetary-scale climate technology; (2) improvements in models for SG deployment that position it as a *near-term supplement* for emissions cuts in alignment with climate capital’s long-term vision of incremental, market-driven climate transitions; and (3) the ideological coincidence between Silicon Valley, financial capital, and SG research programs around ecomodernism and philanthrocapitalism. We will explore the institutions and ideologies advancing SG in the next section. Before doing so, we return again to the question of state intervention in the climate crisis.

Figure 2. Shares of global market capitalization of Weapondollar-Petrodollar and Technodollar coalitions (Bichler and Nitzan 2018)

Extreme technological interventions like SG are emerging as potential forms of climate strategy among the capitalist class because the capitalist state is structurally incapable of intervening at the economic level required to manage the climate crisis. This is not due to “free riding” but a structural limitation produced by the formal separation of ‘the political’ and ‘the economic’ in capitalist societies, which erects barriers to state direction of the capitalist economy. Poulantzas articulates the limits to state intervention starkly (2000: 190–191, original emphasis):

The limits which define the horizon of state action in the economy refer us back to the capitalist relations of production ... the State exists if and only if the hard core of capitalist relations of production is guaranteed, thereby ensuring exploitation of the working class and popular masses ... We may express this by saying that the capitalist state is constituted by a *negative general limit* to its intervention – that is to say, by a specific *non-intervention* in the ‘hard core’ of capitalist relations of production ... to a great extent, but of course within a global strategy of hegemony, state activity is constituted as ad-hoc tinkering with conditions already laid down by the process of valorization of capital; that process itself is not susceptible to mastery by the state.

The limits to state intervention into the ‘hard core’ of capitalist relations of production has major consequences for the climate crisis. We cannot exhaustively outline here what would be required of the capitalist state to deliver a rapid transition to stay below 1.5°C or 2°C by 2100, but it would likely include quickly euthanizing the fossil fuel industry while paying transition costs for workers and fossil-dependent states around the world (Malm 2020), overhauling the electricity grid and transportation system (Burke and Stephens 2018), directing renewable energy development and expansion (Lamperti et al. 2019), regulating and reforming the financial system to foster green

investment (Bozuwa and Hanna 2019), giving land back to Indigenous peoples (Estes 2019), instituting a punitive-level wealth tax to curb excess consumption of the global rich (Boyd 2020), and funding climate reparations including adaptation and technology transfer to the global south (Táíwò and Cibralic 2020).

Given the speed, scale, and level of direct economic intervention required, this appears an impossibility for the capitalist state. Yet, the climate crisis portends a systemic crisis for capital. In this context, *solar geoengineering as a form of state intervention* can fundamentally displace the field of intervention from the economy to the climate system itself. SG is not merely a climate intervention, but a political-economic intervention: in “buying time” for incremental, market-driven shifts to decarbonization preferred by climate capital, it can also slow the devaluation of fossil capital. This tactic can thus blunt the radical urgency of the anti-capitalist climate justice movement and enable status-quo incrementalism, and forge a compromise within the power bloc that rallies the common interest of both the fossil and climate fractions in the stabilization of accumulation, under the dominance of financial capital who is heavily invested in both sectors and thus interested in a transition that avoids a rapid destruction of fossil assets. These points are fleshed out in the final section, where we explore the institutions and ideologies advancing SG in current climate policy.

Section III - Knowledge production and mobilization for SG policy-planning

Leading proponents of SG research and experimentation aligned with climate capital are pushing SG from a last-ditch “plan B” to an integral aspect of *current* climate policy among the liberal technocratic elite. This is evidenced by two recent policy proposals. The first, by Harvard economists Joseph Aldy and Richard Zeckhauser, advocates for inclusion of SG as the “third prong” of “prudent climate policy,” and the second, by David Keith and John Deutch, includes it as the vital “fourth dimension” of climate policy. These papers are of note for three reasons: the institutional positions and affiliations of the authors, the institutions through which they were published and circulated, and the similarities in their arguments for the inclusion of SG in current, market-driven, incremental climate policy. We explore each of these aspects in turn.

The first policy proposal is by Aldy and Zeckhauser (2020). Zeckhauser is a longtime economist at Harvard specializing in decision theory and behavioral economics. Aldy, another Harvard economist, is a fellow at the National Bureau of Economic Research, serves on the board of the Center for Strategic and International Studies, and was Special Assistant to the President for Energy and Environment in the Obama Administration. Aldy is also Chair for the Regulatory Policy Program at Harvard’s Mossavar-Rahmani Center for Business and Government, which is closely affiliated with the Harvard Environmental Economics Program and the Harvard Program on Climate Agreements. The latter are directly involved with HSGRP, and funded by fossil capital corporations Enel, BP, Chevron, and Shell. Moreover, the Mossavar-Rahmani Center’s Advisory Council is largely composed of individuals from financial capital, including BlackRock, Goldman Sachs, and D. E. Shaw.

Aldy and Zeckhauser published their report with Resources for the Future (RFF), a centrist, non-partisan environmental think tank based in Washington, D.C. RFF's board of directors and President's Council are composed of individuals with ties to elite universities, government agencies, and corporations ranging from law (e.g. Bracewell; Covington and Burling) to energy (e.g. Par Pacific; Shell) and finance (e.g. BlackRock; Warburg Pincus). Yet, RFF's corporate *funders*, specifically within its Business Leadership Council, hail primarily from the energy, automotive, and resource sectors e.g. Aramco, Baker Hughes, BP, Chevron, ConocoPhillips, Shell, and Southern Company. Given the composition of leadership and sources of funding, RFF's Topics (areas of research, investment, and advocacy) take a pro-market approach to environmental policy, focusing on carbon pricing, ecosystem services, environmental economics, forest resources, and the oil and gas industries. RFF aims to unite competing corporate sectors – fractions of capital – around environmental issues, and it is in this context that they are promoting economic research that includes SG as a key component of “prudent,” market-based climate policy.

Aldy and Zeckhauser aim to “broaden the policy palette” to include “climate amelioration” – their term for SG (2020, 2). They argue that conventional mitigation strategies have failed: they have been unable to overcome “cheap riding” through carbon pricing and will thus be unable to abate climate change absent both adaptation and “amelioration.” Based on this extremely narrow definition of mitigation, they argue that the “three prongs” of prudent climate policy should include mitigation, adaptation, and SG. They note that these prongs require substantial investment, but will ultimately reduce the significant *costs* of climate change: “a three-prong strategy for climate policy will require political will, policy attention, and major expenditures over a period of many decades. The potential effort will be great, the potential savings in environmental costs far greater” (Aldy and Zeckhauser 2020, 13). They argue that climate change portends severe social and economic costs (citing the potential for a 12-20% reduction in GDP over the next 50 years, p. 5), and push for the inclusion of SG in climate policy because it can *quickly and cheaply* reduce the costs of both climate damages and energy transitions, citing Smith and Wagner's (2018) estimates of approximately \$4 billion per year for an SG program, compared to the *trillions* per year of the other approaches (p. 22).

The second policy paper is by David Keith and John Deutch (2020). We have already discussed some of Keith and HSGRP's corporate connections, but the entrance of Deutch into the SG debate and his association with a prominent SG researcher is significant. He is Institute Professor of Chemistry at MIT, former Director of the CIA, former Deputy Secretary of Defense, has been or is currently on the board of directors of Cheniere Energy, Citigroup, Raytheon, and Schlumberger (an oil services company), and serves as a member of the Council on Foreign Relations, the National Petroleum Council, the Secretary of Energy's Advisory Board, and the Trilateral Commission. Keith and Deutch's paper was written for the Aspen Institute's Economic Strategy Group. The Aspen Institute is an influential economic and foreign policy think tank based in Washington, D.C., with a well-connected board. More specifically, Aspen's Economic Strategy Group (ESG) is co-chaired by former Treasury Secretary and Goldman Sachs executive,

Henry Paulson, and former Morgan Stanley Executive and White House Chief of Staff, Erskine Bowles. Members of Aspen's ESG include governors, former senators, and former treasury secretaries (Timothy Geitner, Jacob Lew, Lawrence Summers), as well as CEOs or CFOs from leading corporations including Alphabet/Google, Bank of America, BlackRock, Blackstone, Bridgewater Associates, Caterpillar, Facebook, General Dynamics, General Motors, and Warburg Pincus.

Keith and Deutch's paper, titled "Climate Policy Enters Four Dimensions," is the concluding chapter of the ESG's 2020 book, *Securing our Economic Future*, and was featured at ESG's annual 2020 meeting. Similarly to their Harvard colleagues, Keith and Deutch frame SG (which they term solar radiation management [SRM]) in climate policy as a question of *costs*. They begin by defining emissions reduction as the process of "lowering emissions *without reducing economic growth*" (267, emphasis added). Dealing with climate change cannot threaten economic growth: this must be the unmitigated priority guiding climate policy. They argue that mitigation is best accomplished through the private market, acknowledging that government policy to create incentives is necessary, but should not venture too far into economic processes in the form of "industrial policy:" "the government record in advancing innovation is mixed; the government does not have the expertise that is necessary to make uncertain investment decisions, and the political system has little tolerance for the failures that inevitably occur with R&D projects" (284). Hence, in this view, as *the market* figures out how to reduce emissions while expanding growth, we need SG as a bridge technology until large-scale carbon dioxide removal (CDR) comes online: "an optimal policy deploys emission reduction early and uses carbon removal at large scale only after emissions have been substantially reduced while [SG] is used for an intermediate period while carbon concentrations are high and is then phased out as concentrations are reduced by CDR" (282), an approach Keith has advocated previously (e.g. Keith and MacMartin 2015).

They argue that this approach has clear economic value. Running integrated assessment models that compare present value of baseline climate damages, the costs of mitigating damages, and the damage incurred after the implementation of control mechanisms, and then modeling out the net present benefit derived from including SG in climate policy *from 2020 to 2220* with a 3 percent discount rate, they demonstrate that the added value derived from including SG in current climate policy ranges between \$39 trillion and \$58 trillion (Keith and Deutch 2020, 283). Given this modeling exercise, they conclude the following: costs of SG appear to be "quite small, with the global annualized costs perhaps under \$20 billion per year well into the latter half of the century. By comparison, the damage-reduction benefits could be 100 times this amount. It seems reasonable that the favorable cost-benefit potential of [SG] justifies a vigorous public R&D effort ..." (287). These two papers represent elite scientists and economists connected to both fossil and climate capital making an argument for the "rational" inclusion of SG in current climate policy – not as a future emergency measure – based on narrow goals of economic efficiency and maintaining market-driven growth, presented to leading figures and institutions within the capitalist class and the liberal technocratic elite.

With funding from tech and finance-linked philanthropists, a political-economic logic that enables state intervention into the climate crisis that avoids large-scale economic planning, and policy proposals demonstrating tremendous cost efficiency, the appeal of SG to the capitalist class becomes clear. Yet naked financial logics and reasons of state are not enough to cement SG into hegemonic climate policy: new ideologies are required. These actors are drawn to SG because it aligns with key aspects of their worldview, namely the belief in technological innovation to solve social problems married with the prudent management of financial risk (see Goldstein 2018). This affinity was articulated in an interview with a geoengineering researcher at HSGRP (interview, 27 February 2018). HSGRP funders:

support the notion that technological innovation could help us address a lot of society's problems ... some of them are people who work in Silicon Valley and for a living believe that technology is something that can move us forward in lots of different ways ... people who work in hedge funds, other financial institutions, I think people who spend a lot of time thinking about "how do you manage risk?," ... if you start looking at climate change risk the same way you might manage financial risk and uncertainty there's some parallels there ... they'll quickly, kind of, wrap their minds around [SG] and think of it that way.

Funding SG research programs on the basis of innovation, risk management, and problem solving fits exceptionally well with the ideology of philanthrocapitalism: a recent, neoliberal manifestation of traditional philanthropy growing alongside the creation of exorbitant private wealth generated by neoliberal policy, and coming to fill some of the crucial public functions simultaneously gutted by it (Hay and Muller 2013; Kapoor 2013).

The world is now awash in philanthropic cash: 72% of new philanthropic organizations have been created since 1995, and billionaires are organizing their efforts through initiatives like The Giving Pledge (founded by Gates and Warren Buffet), which is valued at roughly \$600 billion. Philanthrocapitalism goes beyond traditional giving by changing the function of philanthropy itself, aligning the giving industry with the very same "bureaucratic structures, market-based theories, and corporate organizational strategies" that have generated the enormous fortunes of capitalist philanthropists (Kumbamu 2020). Key funders of SG research, such as Bill Gates and the Open Philanthropy Project, embody this new spirit of capitalist philanthropy. Corporate, billionaire, and celebrity philanthrocapitalism is ultimately designed to smooth out the rough edges of the violently unequal political economy that generates wealth for so few amidst poverty for so many, while aiming to keep this very system intact (Kumbamu 2020; Wilson 2014).

Yet the (white man's) burden of saving the poor through philanthropy is not so heavy when viewed as a positive extension of techno-modernity. Philanthrocapitalists could invest in any number of climate programs – and they do – but SG is unique in speed, scale, and scope in a way that appeals to Silicon Valley. A senior SG governance researcher at Harvard explains this via links to ecomodernism (interview, 5 March 2018):

A lot of the funders, yeah, they're sort of, they're Silicon Valley types. Bill Gates, again, has given us some funding. They're sort of like ecomodernist tech people. So there's a strain of that. There's some New York hedge fund people who just find the whole idea intriguing.

This researcher defines ecomodernism and its affinity with HSGRP as follows:

... basically the idea that technology and, sort of, wise capitalism are going to have to play a central role in addressing the climate problem ... that sort of perspective suffuses, you know, what we do and probably what most of those funders think ... a lot of the, sort of, Breakthrough Institute philosophy...that general approach to these problems is common to both [HSGRP and Breakthrough] and to the larger tech community that's involved in this as some of the funders.

“Wise capitalism” and technological innovation link SG research to The Breakthrough Institute (TBI), the lodestar of ecomodernist thought, and there are myriad connections between TBI and geoengineering researchers. For example, core SG funder Rachel Pritzker chairs TBI's board, and both Pritzker and David Keith are contributing authors to TBI's “Ecomodernist Manifesto,” as is Joyashree Roy, who sits on SilverLining's advisory board.

The Ecomodernist Manifesto argues for an expansion and intensification of capitalist-industrial society to foster the development of “environment-saving” technologies (e.g. nuclear energy, lab-grown meat, etc.) that can “decouple” economic growth from environmental harms and usher in a new era of technologically driven prosperity (Asafu-Adjaye et al. 2015; see e.g. Fletcher and Rammelt 2017; Hickel and Kallis 2019 for critiques of decoupling). Yet for all its claims to innovative modernity, TBI was founded with the political goal of making environmentalism appealing to moderates and conservatives by marrying environmental policy to Silicon Valley-style technological innovation, patriotism, and pro-growth ideologies of capitalism (Kallis and Bliss 2019, 471).

TBI was initially bankrolled by Rachel Pritzker. Pritzker and TBI founders Michael Shellenberger and Ted Nordhaus “had their conversations in the San Francisco Bay Area of the 2000s ... New technologies could make old political stalemates and social problems obsolete, tech evangelists believed. [They] wanted *a narrative that ‘excites the high-tech creative class’* and that talks of ‘America as an innovative nation’” (Kallis and Bliss 2019, 471, our emphasis). SG is in part being developed by some of the same founders of ecomodernist ideology. This small group of “policy entrepreneurs” can be construed in Gramscian terms as organic intellectuals of the high-tech fraction of capital, who work to create and bring to state awareness new policy approaches in line with their economic interests and ideological outlook, and provide policy options on which the state can draw during times of crisis (Carroll 2010).

This imbroglio of political centrism, environmentalism, techno-hype, patriotism, and growth leads Foster (2012) to link ecomodernism, and its forbearer ecological modernization, to capitalist hegemony: ecomodernism is hegemonic in environmental thought because of its “continuous

relation to institutions of dominance ... it derives its peculiar status from the fact that it ‘speaks the proper language,’ that is, the language of vested interests ... the language of business” (Foster 2012, 217). Or, as Collard et al. (2016) succinctly put it: “Ecomodernism claims to apply universally to all, but it is actually a particular and partial vision, offered from a specific place and time (in this case, from an institutional base in Silicon Valley, California) and poised to benefit the same groups who are already at ease in the status quo (Collard et al., 2016: 230).” The very same words could be written of SG: while advocates boost it as a “humanitarian” tool (Horton and Keith 2016), we have demonstrated that SG is rooted in, funded by, and linked to hegemonic fractions of capital and being advanced under extremely narrow, class-based ideologies.

This approach to SG – cost efficiency, market-driven policy, and innovation – being promoted by centrist, technocratic, corporate think tanks has begun to resonate with key figures in the U.S. state. For example, John Deutch recently published a proposal for increasing federal SG research funding to \$50 million authored with Maria Zuber, co-chair of the President’s Council of Advisors on Science and Technology (Deutch and Zuber 2020). This would constitute a major expansion over existing congressional funding: FY20 saw allocation of \$4 million to NOAA to support research, FY21 proposals call for an additional \$9 million, stemming from Representative McNerney’s (D-CA) 2020 Atmospheric Climate Intervention Research Act. This funding pales in comparison to the recommendations made by the NASEM report on “reflecting sunlight,” released in March 2021. The NASEM committee recommends the establishment of a U.S. SG research program funded up to \$200 million for the first five years, housed within the U.S. Global Change Research Program. Two former members of the NASEM committee hold key climate policy positions in the Biden Administration: Andrew Light, Deputy Assistant Secretary of Energy for International Affairs, and Susan Biniaz, the top U.S. lawyer at the Paris Accords who has advocated for SG research and sits on the board of SilverLining, is a lead member of John Kerry’s team as U.S. Special Presidential Envoy for Climate.

Advanced by influential capital-philanthropic-academic coalitions, SG research is now being considered at the highest echelons of U.S. state power. The policy-planning network outlined above is shown in Figure 3 (only capturing organizations in the illustrative cases discussed above, not the complete policy-planning network. Many SG advocates (larger nodes) have short paths to relevant US government agencies (blue squares; average distance 1.4), including the White House (average distance 2.4).

Figure 3. SG policy-planning relationships

Key: Red diamonds = corporations; Blue squares = government; Green triangles = knowledge producers; White circles = individuals; Grey hourglass shapes = key texts. Larger nodes represent SG advocates.

Conclusion

Capitalism's structural drive for constant expansion and accumulation are the root cause of the climate crisis, and the climate crisis – given its capacity to undermine the conditions of capitalist production – portends a systemic crisis for capital. The primary response to this crisis has been “green” or climate capitalism, but, there are fundamental limits to this competitive, market driven approach – not least of which stems from competing fractions of capital within the power bloc – necessitating state intervention to enact the compromises necessary for rapid decarbonization. Yet, given the confines of the capitalist political economy, state intervention in ecologic-economic crises is also fundamentally limited. It is thus increasingly likely that the only way for capitalism to manage climate change on relevant timescales is through the deployment of SG as an integral aspect of near-term climate policy.

The primary actors funding SG as a way to “buy time” for incremental, market-based climate policy are philanthropies and billionaires with myriad connections to corporate power, particularly in the technology and financial sectors. We detail U.S.-based philanthropic funding of SG focusing on connections to specific fractions of capital, demonstrating that – contrary to popular critique – the technology and financial sectors are considerably more invested in SG technology than the fossil fuel industry. We trace this new alignment to the rise of the “technodollar coalition” in the capitalist power bloc vis-à-vis the decline of fossil capital, the shift in approach to SG (from a distant emergency measure to a near-term mechanism to “buy time”), and to shared ideologies of philanthrocapitalism and ecomodernism. We then demonstrate the ways in which this approach is being taken seriously by major corporate-backed think tanks and key segments of the U.S. state.

That SG has moved from the right-wing fringes to high-level government discussions signifies that other attempts to manage climate change from within the narrow confines of capitalism continue to fail, and that the shift in funding sources, aim, and rhetoric around SG research renders the technology more palatable to the state. The inclusion of SG in U.S. climate policy as a temporary supplement to mitigation that has potential “humanitarian” benefits fits exceptionally well within the liberal, technocratic centrism of the Biden Administration and the Democratic Party. Here we are poised to see a state-led class compromise around “climate intervention” that can appeal to both fossil and climate capital, rendering SG a tool of class rule.

Notes

¹ Research in our conception encompasses both scientific and technical processes, as well as efforts to advance governance of SG, considered equally important for its development.

² This is evident in the fact that climate models dependent on these methods for carbon drawdown invariably build in a period of “overshoot” before full-scale Carbon Dioxide Removal – still a speculative technology – comes online (Carton 2020).

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