





Solar geoengineering research on the U.S. policy agenda: when might its time come?

Tyler Felgenhauer ^a, Joshua Horton ^b and David Keith^c

^aThe Duke Center on Risk, Duke University, NC, USA; ^bMossavar-Rahmani Center for Business and Government, Harvard Kennedy School, Cambridge, MA, USA; ^cHarvard Kennedy School, and Harvard University School of Engineering and Applied Sciences, Cambridge, MA, USA

ABSTRACT

Solar geoengineering (SG) may be a helpful tool to reduce harms from climate change, yet further research into its potential benefits and risks must occur prior to any implementation. So far, however, organized research on SG has been absent from the U.S. national policy agenda. We apply the Multiple Streams Approach analytical framework to explain why a U.S. federal SG research program has failed to materialize up to now, and to consider how one might emerge in the future. We argue that establishing a federal program will require the formation of an advocacy coalition within the political arena that is prepared to support such a policy objective. A coalition favoring federal research on SG does not presently exist, yet the potential nucleus of a future political grouping is evident in the handful of ‘pragmatist’ environmental organizations that have expressed conditional support for expanded research.

KEYWORDS Solar geoengineering; agenda-setting; environmental politics; climate change policy; United States; multiple streams approach

1. Introduction

Solar geoengineering (SG), also known as solar radiation management or modification (SRM), or solar climate intervention, would enhance the reflectivity of the planet to offset some effects of climate change. One method, stratospheric aerosol injection (SAI), would disperse a small quantity of aerosols in the stratosphere to accomplish this. Early research indicates that moderate use of SG technologies like SAI could significantly reduce some climate risks quickly and at relatively low cost (Irvine *et al.* 2019). As such, these technologies may constitute a powerful tool in a portfolio of climate responses that includes mitigation, carbon dioxide removal, and adaptation (Aldy and Zeckhauser 2020, Keith and Deutch 2020). Yet the possible climatic benefits, risks, and implementation pathways of SG present considerable uncertainty.

CONTACT Tyler Felgenhauer  tyler.felgenhauer@duke.edu

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Despite such potential, national governments have remained relatively disengaged from the topic. Only a small amount of government-sponsored research is taking place globally, and very few countries have official policies regarding SG. Although a relatively high proportion of global research is occurring in the United States (Necheles *et al.* 2018), it is mostly funded by private sources at levels that are miniscule compared to total federal spending on climate research.¹ Currently, the U.S. government lacks both a formal policy on SG and a dedicated research program, although a recent National Academies report calls for the creation of the latter (NASEM 2021).

SG could have serious implications for both economic growth and global politics. Considering its potential to shape future world events, why has the U.S. government devoted such little effort to researching these technologies, and what might it take to move research onto the national agenda? In this article we apply the Multiple Streams Approach (MSA), a theoretical framework to explain agenda-setting in diverse policy domains, to explore why research into SG has been absent from U.S. climate policy and how that situation might change.

We would consider SG research to be ‘on the U.S. policy agenda’ if serious debate were to occur over the creation of a federally-funded SG research program. Compared to limited appropriations or discrete projects, a research *program* on SG, which we define as an organized research effort involving multiple projects investigating natural and social science dimensions of SG, would provide the government and the public with a more comprehensive view of the potential benefits, costs, and risks associated with these technologies. Such a program could entail modeling, small-scale outdoor experimentation, and other analyses conducted to answer physical science, engineering, and environmental questions, as well as research on socio-economic, political, and ethical issues. We are focused on SG *research*, not on technology development or implementation.

This article breaks ground in two ways: first, to our knowledge MSA has not previously been applied to SG; and second, our analysis involves a rare *prospective* use of MSA in which the framework is applied to a policy question *before* a proposal makes it onto the agenda. In [Section 2](#) we lay out the key elements of the MSA framework. In [Section 3](#) we describe the relevant features of the current U.S. policy landscape. In [Section 4](#) we explore the conditions under which SG research might be seriously considered at the national level. [Section 5](#) concludes.

2. The multiple streams approach to understanding agenda-setting

The MSA framework originated by Kingdon (1984, 1995) is arguably the most utilized analytical schema for explaining how issues arrive on the public

policy agenda (Zohlnhöfer *et al.* 2015, Cairney and Jones 2016, Jones *et al.* 2016). MSA is built on the ‘garbage can’ model of organizational choice in which decision-making, rather than following a linear or rational process, is instead the ‘outcome or interpretation of several relatively independent streams within an organization’ (Cohen *et al.* 1972, pp. 2-3). In this understanding, ‘... an organization is a collection of choices looking for problems, issues and feelings looking for decision situations in which they might be aired, solutions looking for issues to which they might be the answer, and decision makers looking for work’ (Cohen *et al.* 1972, p. 2).

Building on this approach to organizational dynamics, Kingdon focused specifically on the nature of the policy agenda, or ‘the list of subjects or problems to which governmental officials, and people closely associated with those officials, are paying some serious attention at any given time’ (Kingdon 1995, p. 3). In particular, Kingdon sought to understand why attention is paid to certain topics, how the agenda changes, and how a large set of policy alternatives is narrowed down to just a few; in other words, ‘Why does an idea’s time come when it does?’ (Kingdon 1995, p. xi).²

In considering agenda-setting, MSA posits that decision-makers have limited attention spans and operate in a turbulent policy environment that consists of three independent ‘streams’ – a problem stream, a politics stream, and a policy stream – each of which is characterized by its own fluctuations and idiosyncrasies. These and other elements of the framework are described below and summarized in [Figure 1](#).

2.1. The three streams

The *problem stream* contains issues that are subjectively deemed problematic and deserving of attention by public actors. Objective conditions in the world evolve according to their own processes; these conditions are defined or framed as problems ‘... when we come to believe that we should do something to change them’ (Kingdon 1995, p. 198). Problems may be formally or informally monitored using quantitative or qualitative ‘indicators’ tied to specific conditions (like the unemployment rate) as well as ‘feedback’ from stakeholders and publics. Problems may arise gradually, or they may develop suddenly in response to an abrupt ‘focusing event’ (discussed below). Sometimes a problem emerges when perceptions shift and people decide that a situation previously tolerated is no longer acceptable. The salience of a problem fades when it is considered to be resolved (or at least adequately debated or otherwise addressed), when budgetary or other constraints make solutions seem unachievable, or when top decision-makers and opinion leaders are distracted by the rise of other problems.

The *politics stream* consists of public opinion, electoral and interest group politics, and political party ideologies. Politicians seek to both shape and

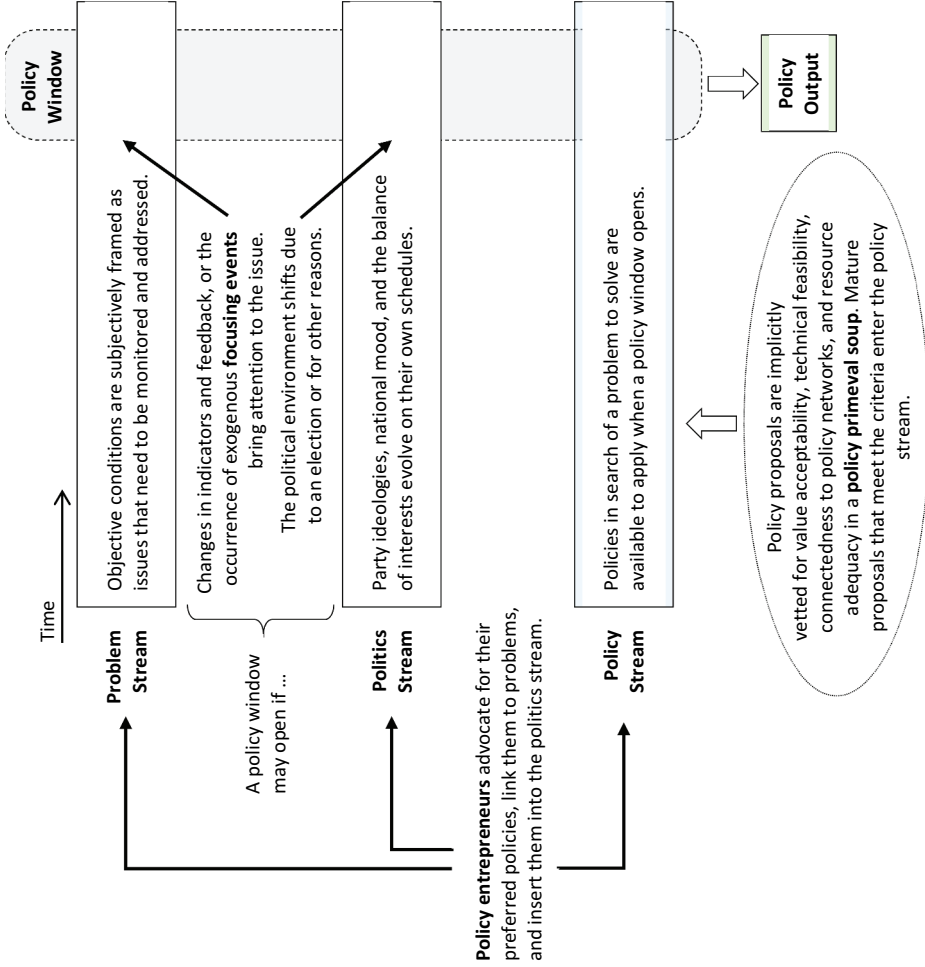


Figure 1. The Multiple Streams Approach, adapted from and modifying Morgan (2017) Figure 16.1 and also drawing from Zahariadis (2014) Figure 2.1.

discern the national mood. Bureaucratic turf wars can increase issue awareness. As Kingdon writes, 'In contrast to the policy stream's emphasis on persuasion, the political stream's consensus building is governed by bargaining' (Kingdon 1995, p. 159).

In the *policy stream*, government officials, Congressional staff, academic researchers, advocacy groups, and others develop and refine possible solutions to different problems. Alternative proposals are devised and vetted in what Kingdon terms the 'policy primeval soup,' a competitive intellectual marketplace where potential policies vie for attention and evolve in response to selection pressures. Policy proposals are most likely to emerge as viable options if they are compatible with widely held values, technically feasible, adequately resourced, and sufficiently connected to influential policy networks.

2.2. Policy windows, focusing events, and policy entrepreneurs

Within MSA, the problem, politics, and policy streams flow continuously and independently. Occasionally, temporary 'policy windows' may open due to changes in the politics and/or problem stream. Changes in the politics stream may be predictable (e.g., following regular electoral or budget cycles) or unpredictable (e.g., precipitated by unexpected political swings or changes in national mood). Changes in the problem stream may track with changes in indicators or feedback, or they may stem from the random and unanticipated occurrence of a 'focusing event like a crisis or disaster that comes along to call attention to the problem' (Kingdon 1995, pp. 94–95). Focusing events are often associated with disasters, including 'natural' disasters typically driven by natural phenomena combined with social failures. It is important to note, however, that 'a focusing event by itself is often an insufficient driver of policy change' (Birkland and Schwaeble 2019, p. 5).

An open policy window creates an opportunity for 'policy entrepreneurs' – 'people who are willing to invest their resources in pushing their pet proposals or problems' (Kingdon 2014, p. 20) – to advance policies they support by merging the three streams using a 'coupling logic' (Blum 2018). If change begins in the problem stream, a policy entrepreneur will promote a proposal as a response to the problem as it is collectively understood. Alternatively, if change begins in the politics stream, a policy entrepreneur will look to match a proposal with a suitable problem. The success of policy entrepreneurs in helping to couple the three streams and ultimately set the agenda is a function of their access to decision-makers, the resources available to them, and the strategies they employ. In particular, effective policy entrepreneurs possess social acuity and are good at defining problems, building teams, and leading by example (Mintrom and Norman 2009).

MSA theory has been widely applied to explain agenda-setting across a wide range of countries, levels of government, and public policy domains. The approach has been used to investigate many dimensions of climate policy in particular, including inter alia emissions trading in Germany (Brunner 2008), the development of climate change adaptation policies in the United Kingdom, Sweden, Finland and Italy (Keskitalo *et al.* 2012), the U.S. Greenhouse Gas (GHG) reporting rule (Cook and Rinfret 2013), and bringing aviation into the European Union Emissions Trading Scheme (Buhr 2012).

3. The current U.S. policy landscape: solar geoengineering research off the agenda

Here we describe the current status of SG research as a potential but unrealized agenda item in U.S. national climate policy. Against the background of a climate change problem that is widely recognized but insufficiently addressed, a small number of researchers and policy analysts are now discussing SG as a possible policy response. Yet, as we elaborate below, SG is presently characterized by low public awareness, conflicting and generally skeptical views within the environmental community, and very little government interest. In this context, experts have repeatedly but unsuccessfully called for the creation of a dedicated U.S. federal research program.

3.1. The problem of climate change

The basic problem in relation to which SG is being considered is global climate change. In terms of the MSA framework, many indicators are used to track the climate problem. The increase in global mean temperature compared to particular baselines – for example, preindustrial levels or the period 1986–2005 (IPCC) – is one common approach. Another is the atmospheric concentration of CO₂ or GHGs (often expressed as CO₂-equivalent) in parts per million, most often compared to preindustrial baselines. A more recent indicator is the so-called carbon budget, or the estimated maximum amount of additional emissions allowable before certain thresholds – typically 1.5° or 2°C above preindustrial levels – are expected to be exceeded. In the United States, these and other metrics as well as anticipated national climate impacts and risks are reported every four years in a National Climate Assessment (USGCRP 2018).

Although climate change has long been debated in the United States, meaningful policies to constrain emissions remain lacking. The Waxman-Markey Bill (U.S. House 2009) proposed a nationwide cap-and-trade system but failed to pass. The Obama Administration's Clean Power Plan targeting coal-fired power plants was repealed by the Trump Administration. The

Biden Administration has identified climate action as a top priority and rejoined the Paris Agreement (White House 2021), but whether this will translate into measurable success is an open question. What is most important from the MSA perspective, however, is the fact that sufficient institutional capacity clearly exists to at least consider climate change as a public policy issue.

It is in this context that a handful of U.S. researchers and other interested stakeholders have suggested that SG should be investigated as an additional climate policy response option. Climate models consistently agree that uniform SG – used in combination with emissions cuts – could greatly reduce many of the climate changes that most drive human impacts, including extreme storms, water availability, and extreme temperatures (Ji *et al.* 2018, Irvine and Keith 2020). Evidence suggests it is plausible that SG could reduce the net cost of climate harms by more than a factor of two while also reducing income inequality (Harding *et al.* 2020). Yet the prospect of expanded research on SG, including the possibility of outdoor experiments, elicits sharply divergent views.

3.2. The politics of solar geoengineering in the climate context

Public awareness of and concern about climate change is considerable, but it is generally unmatched by a willingness to support policy changes that would impose significant costs to reduce carbon emissions. In a recent survey, a majority of U.S. adults considered climate change to be either a ‘crisis’ or a ‘major problem’ (Hamel *et al.* 2019). Yet majorities opposed raising taxes on electricity or gasoline to pay for emissions cuts; 38% were ‘somewhat worried’ that mitigation efforts would hurt average Americans, and 23% were ‘very worried.’ In another recent survey, roughly two-thirds of respondents said that climate change was affecting their community either ‘a great deal’ or ‘some,’ and two-thirds said that the federal government was doing too little to reduce the effects of climate change (Tyson and Kennedy 2020).

Compared to awareness of climate change, public awareness of SG is significantly lower. A 2010 survey of 2,893 adults in the United States, Canada, and the United Kingdom found that 20% of respondents had heard of ‘geoengineering’ and 24% had heard of ‘climate engineering,’ though only 8% and 45%, respectively, could accurately define these terms (Mercer *et al.* 2011). A 2016 online survey of 1,000 U.S. adults asked them to rate their familiarity with SG on a scale of 1 (‘not at all familiar’) to 4 (‘very familiar’). The mean response was 1.7, and nearly 57% of respondents were ‘not at all familiar’ with SG (Mahajan *et al.* 2019).

Environmental nongovernmental organizations (NGOs) are more familiar with SG than the general public, but few of them have staked out clear positions on these technologies. The U.S. environmental community is large

and complex, with organizations that vary by size, structure, focus, beliefs, and tactics (Brulle 2015). Environmental organizations can be roughly divided into two camps. On one side are ‘insider’ groups that directly lobby decision-makers and broadly espouse what has been called ‘reform environmentalism,’ a perspective that promotes ‘technological development and energy efficiency’ and ‘the use of market-based user fees for pollution, tax incentives, increases in energy efficiency, or the shifting of production toward green products’ (Brulle 2015, p. 153). Reformists consider their approach politically realistic.

On the other side are ‘outsiders’ that seek to exercise influence indirectly via the media and/or the public using campaigns, events, and protests. These groups typically embrace some form of ‘preservationism,’ which ‘focuses on embedding environmental and ecological concerns in society through the reconfiguration of existing political and economic institutions’ (Brulle 2015). Preservationists are more opposed to science and technology and interventions in nature. Real-world differences among environmental groups are of course significantly more complex than any simple division between reformists and preservationists. Nevertheless, this simplified stratification has exhibited relative stability over time (Hein and Jenkins 2017, Brulle 2018).

On SG specifically, no group supports deployment, but a small number of insider legacy organizations – referred to by Zeller (2017) as ‘pragmatists’ – have expressed conditional support for research. The Environmental Defense Fund (EDF) and the Natural Resources Defense Council (NRDC) have jointly stated ‘that engaging in transparent small-scale field research to further understanding of the climate system and the implications of any solar geoengineering proposals is prudent’ (CAN 2019).³ Similarly, the Union of Concerned Scientists (UCS) ‘believes that a precautionary approach to climate risks includes developing an understanding of the risks and efficacy of solar geoengineering: UCS ... believes smaller-scale outdoor experiments should only go forward if legitimate independent governance mechanisms are established’ (CAN 2019; see also UCS 2020).

Other establishment groups are either opposed to SG or agnostic on the issue; Zeller (2017) refers to these as ‘purists.’ Friends of the Earth-US (FOE-US) maintains that ‘geoengineering will take us in the wrong direction,’ and ‘would condemn any proposals to move geoengineering towards real world experimentation’ (FOE-US 2015). The Sierra Club is likewise dubious, but its strategic Climate Adaptation Task Force ‘does not see a major role for the Sierra Club on SRM issues, except to monitor U.S. actions and research and take action to oppose any U.S. deployment’ (Sierra Club 2019). The National Wildlife Federation appears not to have taken a position on SG. Newer NGOs built on social media and focused exclusively on climate are either silent about SG or openly hostile toward it. For example, the programme director for 350.org has stated that ‘solar radiation management ... might actually make

things worse if implemented only in some places or suddenly stopped. The hard truth is we can't engineer our way out of the climate change mess' (350.org 2018). Neither the Sunrise Movement nor other emerging groups like Green for All appear to have adopted explicit positions on SG.

Although pragmatists and purists have yet to aggregate into clearly identifiable political coalitions on the question of SG and associated research, it is possible to discern what may be interpreted as the emergent outlines of such groupings. In 2019, the Climate Action Network (CAN), a global network of environmental NGOs deeply involved in global climate politics, publicly declared its opposition to SG in a position statement (CAN 2019). Of the more than 1,500 organizations on whose behalf CAN spoke, three added reservations to this statement: EDF, NRDC, and UCS (their reservations are quoted above), with EDF and NRDC making a single joint reservation. Presumably, U.S. NGOs contributed to formulating this position statement at least in part via the U.S. Climate Action Network (USCAN), which suggests that these three pragmatist groups consciously chose to distance themselves from the purist position adopted by the other members of USCAN (including FOE-US, the Sierra Club, and 350.org), with at least EDF and NRDC coordinating their actions. Despite these early signs, however, for now NGO views on SG remain largely unsettled and in flux, with many groups yet to articulate their views and those few that have come out in conditional support of research clearly uneasy at the prospect.

Elsewhere on the left of the political spectrum, NGO anxiety is accompanied by lack of interest from the donor community (Nisbet 2018) and avoidance on the part of think-tanks, apart from the Breakthrough Institute (McInnes 2013) and more recently Resources for the Future. Given such reluctance on the part of organized liberal and progressive interest groups, the topic of SG was almost completely absent from the 2020 Democratic Party primaries and platform. In the center, only the Bipartisan Policy Center (2011) and the Wilson Center (Nicholson 2020) have engaged with the issue. On the right, except for passing interest shown by the American Enterprise Institute, the Niskanen Center, and the Heartland Institute (Harris and Ball 2018), think-tanks have generally stayed away from SG (Collomb 2019). The business community, including fossil fuel companies, has similarly remained aloof (Reynolds *et al.* 2016). In light of the relative indifference exhibited by influential conservative actors, the Republican Party has also refrained from taking up the issue (with the occasional exception (Smith 2018)).

Given its lack of salience within either leading political party, attention to SG on the part of the executive and Congress has been fleeting. In the former, the U.S. Global Change Research Program (USGCRP), which steers climate research across fourteen government departments and agencies, endorsed SG research in a 2017 strategy document (USGCRP 2017). SG was briefly discussed in the 4th U.S. National Climate Assessment (USGCRP 2018) and its supporting Climate

Science Special Report (DeAngelo *et al.* 2017). Several federal entities funded a 2015 report by the National Academies, which backed the creation of a national SG research program (National Research Council 2015). A successor National Academies report on SG research and research governance released in March 2021 (NASEM 2021) put forward a more detailed plan (discussed in the next section). In Congress, a series of hearings on SG was held over 2009–10 by the House Committee on Science and Technology (U.S. House 2010a, 2010b), and further hearings were held in 2017 by the House Committee on Science, Space, and Technology (U.S. House 2017a). More recently, the House Select Committee on the Climate Crisis recommended the establishment of a federal research program on ‘atmospheric climate intervention’ approaches (U.S. House 2020b, p. 526). Representative Jerry McNerney (D-CA) has introduced two bills on SG, one to develop a research strategy and a second to fund such research (U.S. House 2017b, 2019), but neither have reached the full floor.

3.3. U.S. federal solar geoengineering research as a policy response

Policy discussions about SG in the United States are beginning to crystallize around the idea of a federally-funded research program. Outside calls for dedicated research have emanated from academia (AGU 2018, Parson and Keith 2013, MacMartin and Kravitz 2019, Keith and Deutch 2020) and think tanks (Bipartisan Policy Center 2011, Majkut *et al.* 2017). SilverLining, a nonprofit advocacy group, has proposed a set of ten-year research objectives (Wanser *et al.* 2019). As noted above, within the executive branch USGCRP has endorsed the need for federal research (USGCRP 2017). Calls for a national program are motivated by a number of concerns, including the scale of resources required, the public nature of the SG, the need for transparency, and a desire to preempt commercial development and assertions of intellectual property rights.

Among those who support a national program, views differ on whether research should go beyond indoor laboratory work and computer modeling to encompass small-scale outdoor field experiments, whether technology development and engineering should be funded, and whether social science and humanities research, including work on research governance, should also be supported. The amount of resources committed, the duration of support, and institutional issues regarding the management and distribution of research effort are all questions that remain unsettled. To date, no policy entrepreneurs or other actors have advanced a comprehensive, fully developed research plan for public consideration.

4. What are the necessary conditions for solar geoengineering research to be on the U.S. policy agenda?

According to the MSA framework, three developments must occur for an issue to get on an agenda. First, changes in the problem and/or politics stream must open a policy window. Second, a proposal within the policy stream must meet basic criteria of feasibility. And third, effective policy entrepreneurs must take advantage of the open policy window by coupling the three streams together successfully. Here we apply these requirements to the case of SG research. We hypothesize that the primary predictive factor that will determine whether SG research rises onto the U.S. national policy agenda – in the form of one or more proposals for a federally-funded research program – is the balance of interests within the environmental advocacy community. As noted above, the current center of gravity within the community is best described as latent opposition, though this is subject to change.

4.1. Open policy window

For a policy window to open, one or more significant changes must occur either in the problem stream, the politics stream, or both. Looking first at the *problem stream*, one might argue that an appropriate focusing event could trigger a collective reassessment of the climate problem sufficient to create an opening for SG research to get on the policy agenda. The assumption in this line of argument is that some future climate-related disaster might be so serious or shocking as to quickly shift the climate discussion to consider new, unconventional approaches to addressing climate change. The problem with this argument, however, is that it further assumes that key political actors would be open to considering an idea like SG and prepared to support a federal research program to investigate it, when as we have shown they currently are not. Birkland and Schwaeble delineate the limits of focusing event influence on agenda-setting as follows: ‘Under what conditions are focusing events most likely to lead to change? . . . the size and amount of attention garnered by the event is just one part of this. The composition of the policy subfield also matters, such as whether those dominant in the policy area have interests that align with potential policy congruent with a response to the focusing event’ (Birkland and Schwaeble 2019, p. 10).

If a future climate disaster could be interpreted as justifying serious consideration of a novel policy approach like SG, such an interpretation would only have policy salience to the degree that key political actors – in this case, environmental NGOs – are amenable to it. But all things being equal, the response of these groups would much more likely be to call for more ambitious mitigation. And this is precisely what has happened following the

most high-profile, destructive extreme weather events that have struck the United States over the past decade (during which time SG was openly discussed). Widespread drought in 2012; Hurricanes Sandy in 2012, Harvey, Irma, and Maria in 2017, Florence and Michael in 2018, and Laura in 2020; and western wildfires in 2017, 2018, and 2020 were all met with demands for swifter decarbonization (and to a lesser extent more adaptation).

We contend that whether a policy window opens for SG research will depend primarily on events within the *politics stream*, specifically on whether the incipient pragmatist grouping of environmental NGOs favorably disposed toward research coalesces into a more institutionalized political coalition aimed at getting such research on the national agenda. Indeed, coalitions are integral to the agenda-setting process because the bargains that drive the politics stream – including the changes that open policy windows – are expressed through coalitions. Moreover, as part of a broader integrative move, MSA theorists are increasingly conceptualizing these coalitions specifically as *advocacy* coalitions: ‘the ‘politics’ stream can be thought of as being the milieu where “*advocacy coalitions*”, a term used by students of American policymaking to describe the activities of those involved in the political struggle surrounding the matching of problem definitions and policy tools . . . are most active. These actors compete to get their choice of problem definitions as well as solutions adopted during the policy process’ (Mukherjee and Howlett 2015, p. 70, emphasis original). Furthermore, ‘although often posited . . . as comprising all actors within a policy subsystem, the role of advocacy coalitions in vying to get their preferred problem and solutions chosen in policy decisions implies that, consistent with Kingdon’s ideas, they can more usefully be thought of as synonymous with activities in the politics stream’ (Mukherjee and Howlett 2015, p. 71).⁴

An advocacy coalition consists of ‘people from a variety of positions (elected and agency officials, interest group leaders, researchers) who share a particular belief system – i.e., a set of basic values, causal assumptions, and problem perceptions – and who show a non-trivial degree of coordinated activity over time’ (Sabatier 1988, p. 139). From our discussion of the contemporary politics of SG above, such a coalition does not yet exist in the politics stream. Looking forward, however, the elements of a potential advocacy coalition supporting federal research on SG come into focus. These include Representative McNerney, USGCRP, and, most significantly, the emergent pragmatist grouping of EDF, NRDC, and UCS within the environmental community. These organizations are notable both because they have been the most deeply involved with the issue over time, and because they have exhibited a degree of coordination in formulating their positions, especially EDF and NRDC in the context of the 2019 CAN position statement. Continuing interactions among some combination of these and other

groups could form the nucleus of an incipient advocacy coalition favoring a federal research program on SG. Such a coalition would probably encompass other legislative, executive, party, and/or interest group actors that subscribe to some version of reform environmentalism. Advocacy Coalition Framework theorists hypothesize that successful coalition formation depends on low transaction costs, exaggerated benefits, and/or weak coordination requirements (Sabatier and Weible 2019, p. 197).

When trying to set the agenda based on political bargains, policy entrepreneurs must rely on coalitions; without a coalition, an entrepreneur has no fixed position from which to couple the policy, problem, and politics streams. This may seem obvious, but from the vantage point of an MSA framework normally focused on explaining past events, the political terrain on which agendas are contested will typically already have been established at the point that analysis begins, thereby obscuring the fact that politics must unfold, interests must cohere, and coalitions must emerge before the agenda can be set. Identifying the need for advocacy coalition formation prior to policy entrepreneurship simultaneously: 1) elevates the importance of the emergent pragmatist grouping of NGOs conditionally open to SG research, 2) pinpoints what we regard as the key to opening the policy window in this case, 3) demonstrates the utility of prospective MSA theorizing, and 4) underlines the potential for theoretical integration of existing models of the policy process. We return to the latter two points in the conclusion.

4.2. Viable policy proposal

The second requirement for this issue to be on the agenda is the availability within the policy stream of a feasible ‘solution’ that addresses the problem. As noted above, from the MSA perspective, the viability of a policy proposal depends on its technical feasibility, its resource adequacy, its connectedness to policy networks, and its compatibility with widely held values. A federal research program might be expected to fund computer modelling, laboratory experiments, social science and humanities research, and observations and field experiments. A research program is technically feasible. In terms of resources, an expert elicitation of IPCC authors in the United States and China conducted in 2018 (Dai *et al.* 2021) revealed support for 200 USD million in annual research funding for SG (compared to the current level of 2.5 USD billion per year for climate change research across the federal government). Based on prior experience, NOAA, NASA, DOE, and/or some other federal agency or entity would likely lead such a program, with USGCRP potentially playing a coordinating role. The expertise embodied within these organizations, combined with sufficient funding, would ensure that such a program is adequately resourced as well as connected to existing climate science and policy networks.

As for compatibility with widely held values, we believe a good proxy for this would be the credibility of steps taken to address concerns about a potential slippery slope, in which early research leads inexorably to deployment. Protective measures to prevent this outcome might include some combination of program-wide oversight by stakeholders, clear decision points at which further research can be halted ('stage-gates'), and institutional barriers between programs and program elements for which separation is desirable ('firewalls'). Such an effort could be built within the USGCRP framework (Bipartisan Policy Center 2011).

A research program that is well-organized, technically sound, adequately funded, tied to existing climate science research efforts, and designed to address societal concerns would likely fulfill the criteria for a successful policy proposal. The McNerney bills had the potential to meet some of these requirements: the 2017 bill (U.S. House 2017b) instructed the NAS to establish research priorities and OSTP to submit a corresponding plan for research (and for research governance) to Congress, and the 2019 bill (U.S. House 2019) assigned a lead role to NOAA. The recent National Academies report (NASEM 2021) puts forward a more comprehensive vision for a federal SG research program with funding of 100–200 USD million over the first five years in support of a range of coordinated natural and social science investigations including small-scale outdoor field experiments, overseen by USGCRP.⁵ Yet, prior NAS reports in 1982, 1991, and 2015 also recommended research, albeit with less specificity, suggesting that an NAS report alone may not have much impact without the larger conditions that define a policy window.

4.3. *Effective policy entrepreneurs*

To be effective, policy entrepreneurs must be active and interested, and able to deploy effective coupling strategies to merge the policy stream with either the problem stream or the politics stream, and preferably with both. Currently, SilverLining is the most identifiable candidate for the role of policy entrepreneur. This advocacy group has worked with Rep. McNerney in Congress, and in 2019 it called for a coordinated ten-year multi-agency federal research effort (Wanser *et al.* 2019). To the best of our knowledge, no other organizations are focused on promoting a SG research program, though a range of policy academics, including one of this article's authors, and a few Washington, DC-based policy experts have long actively promoted such research in testimony at multiple hearings with Congress (U.S. House 2010b, 2017a) or in conversations with the executive branch. Other actors, perhaps other NGOs, could conceivably play this role. But so far only SilverLining has exhibited the type of active, organized, sustained, and

singularly focused political engagement that is characteristic of policy entrepreneurs who succeed at agenda-setting.

5. Conclusions

We have used the MSA framework to consider why the United States lacks a federal SG research program, and how one might emerge. The critical factor, in our view, relates to the lack of an advocacy coalition that supports federal research. In the absence of such a coalition, would-be policy entrepreneurs have no platform from which to attempt to link a research proposal to the climate problem. With such a coalition providing support, an effort by policy entrepreneurs to make such a link – with or without a focusing event – would be relatively straightforward and stand a good chance of success. In other words, an open policy window enabling agenda-setting depends in this case on the emergence of a political coalition in favor of federal research.

We have further argued that such an advocacy coalition would need to be built around the emergent pragmatist grouping of environmental NGOs – presently consisting of EDF, NRDC, and UCS – that has voiced conditional support for research. Currently, these organizations are not forceful advocates for SG research, and they may never be. Unless and until these or similar groups begin to coordinate their advocacy and join with like-minded actors to promote federal research, a comprehensive program is unlikely to get on the national agenda.

Only by using the MSA framework to theorize prospectively about what would likely be necessary for agenda-setting to occur were we able to identify the importance of advocacy coalition formation. While this has unavoidably involved some degree of speculation, we believe it has helped bring to the fore an essential condition that explains why agenda-setting has not occurred up to now, and what it would take for that to change. In so doing, such prospective theorizing has also helped illuminate a key conceptual link between MSA and the Advocacy Coalition Framework, buttressing growing calls for greater theoretical integration emanating from public policy scholars.

The central importance of coalition formation in agenda-setting is strongly suggested by the recent establishment of a federal research program on carbon removal (U.S. House 2020a). The evidence suggests that this program derives from work initiated by the Carbon Capture Coalition in 2019 (Carbon Capture Coalition 2019). This grouping began as the National Enhanced Oil Recovery Initiative in the early 2010s, which brought together business, labor, environmental groups, and others to advocate for revised federal tax credits ('45Q') to incentivize carbon utilization, and subsequently broadened its goals to include promotion of carbon capture and storage and direct air capture technologies. Just as formation of the Carbon Capture Coalition appears to have been

essential to getting first revised 45Q and now a federal carbon removal research program on the national agenda, our analysis indicates that something comparable will be required if SG research is to attain similar status.

Notes

1. The National Oceanic and Atmospheric Administration (NOAA) recently received \$4 million from Congress to study SAI as well as marine cloud brightening (Fialka 2020). House and Senate appropriations bills for FY2021 proposed an additional \$5 million, and the Senate version included funding for the National Aeronautics and Space Administration (NASA) (Talati 2020).
2. Agenda-setting is only one component of the broader policy cycle; it is distinct from policy adoption and implementation.
3. This built on earlier statements by both organizations (Frumhoff 2015, Heyd 2015).
4. The concept of advocacy coalitions is central to the Advocacy Coalition Framework, which seeks to explain the effect of beliefs on policy outcomes. While often seen as competing with MSA as a meta-theory of the policy process, researchers increasingly view these frameworks as complementary and are working to integrate them theoretically, e.g., Howlett *et al.* (2017).
5. Significantly, one member (Peter Frumhoff) of the sixteen-person committee responsible for this report serves as Director of Science and Policy and Chief Climate Scientist for UCS.

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ORCID

Tyler Felgenhauer  <http://orcid.org/0000-0001-9122-0444>

Joshua Horton  <http://orcid.org/0000-0003-3606-6039>

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