



# Solar geoengineering research programs on national agendas: a comparative analysis of Germany, China, Australia, and the United States

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## Abstract

Solar geoengineering (SG), or the proposed use of technology to reflect sunlight back to space as a means of partially counteracting climate change, requires systematic research funded by public bodies, yet no dedicated national SG research programs (“programs”) currently exist. To explain why and understand how things might change in the future, we add concepts from role theory, a research tradition focused on international relations and foreign policy analysis, to the Multiple Streams Approach, a theoretical framework developed to study agenda setting at the national level, to assess policy processes related to SG research in four countries: Germany, China, Australia, and the United States (US). The results of our analysis indicate that, among these four states, only the US might plausibly consider initiating a program under present conditions. Germany, China, and Australia appear likely to seriously consider comparable efforts only in response to a US program, although their reasons for doing so and specific program designs would differ. The source of this variation, we argue, is the different foreign policy paradigms—or “national role conceptions”—prevailing in each state, which mediate between domestic and international politics and help define which policy proposals qualify as viable in different countries. From a policy perspective, this suggests that the global trajectory of SG depends disproportionately on developments in the US.

**Keywords** Solar geoengineering · MSA · Programs

## 1 Introduction

Solar geoengineering (SG), or the proposed use of technology to reflect sunlight back to space as a means of partially counteracting climate change, is not merely a novel emerging technology but also a novel policy field, with few governments giving it anything more than cursory attention. Answering some of the most salient questions about the technology,

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however, will require sizable and sustained public funding. National SG research programs (“programs”), perhaps linked internationally, will likely constitute the first systematic steps toward strengthening our collective understanding of SG, and yet, as we detail in this article, no such programs currently exist. Why is this the case, and what if anything might change it? This is our central research question.

To begin to answer it, we adopt the exploratory case study method to consider whether and, if so, how foreign policy paradigms influence the domestic agenda-setting process (Streb 2010). More specifically, we apply this method to recent historical events to enable disciplined speculation regarding probable near-term policy trajectories. Our approach is fundamentally exploratory: our prognoses are not predictions but rather projections of how current conditions are likely to favor certain outcomes over others. Our purpose is to inform early policy discussions, not to generate falsifiable hypotheses. The propositions we develop thus should be viewed as initial formulations.

Our analysis is based on the Multiple Streams Approach (MSA), a theoretical framework created by John Kingdon to shed light on how policy proposals get placed on national agendas (1984). MSA understands agenda setting as the confluence of three “streams” of activity—the problem, politics, and policy streams—partially shaped by “policy entrepreneurs” and ultimately dependent on open “policy windows.” MSA is not focused on whether policy proposals are adopted, but rather whether they are seriously considered for adoption.

While MSA is widely regarded as one of the bedrock theoretical approaches used in public policy analysis, like any such approach it has limitations. One such limitation is that MSA tends to insufficiently constrain the scope of possible proposals to a smaller subset of genuinely viable policy options. Without narrowing this scope, analyses based on MSA run the risk of being insufficiently precise, which in turn limits the utility of the knowledge they produce.

To supplement MSA in this regard, we borrow the notion of “national role conceptions” (NRCs) from role theory, a longstanding research program in International Relations and foreign policy analysis that highlights the significance of such conceptions as intervening variables that simultaneously shape the ways in which states respond to the international system and affect the ways in which states influence that system (Harnisch 2011). We hypothesize that NRCs—foreign policy paradigms—help set boundaries around what qualifies as viable in agenda setting, particularly for issues with domestic and foreign policy implications.

Equipped with this revised apparatus, we examine the agenda-setting process in four states at the forefront of developments in SG: Germany, China, Australia, and the United States (US). These are the four countries that have hosted activities related to SG of sufficient scale and scope to support expectations that they might adopt dedicated programs. We define a national SG research program as characterized by four key attributes. First, it is national in that it is organized at the central level of government. Second, it is dedicated to investigating SG. Third, it includes more than one research project. Finally, it is substantial in scale. As a funding benchmark, we use the figure of \$100–\$200 million spread over five years recommended by the US National Academies of Sciences, Engineering, and Medicine (NASEM) in its 2021 report *Reflecting Sunlight*.

The article proceeds as follows. First, we will provide a theoretical background summarizing MSA and role theory in which we highlight how NRCs may serve a vital function in constraining what actors regard as viable in the agenda-setting process. The next four sections apply the MSA framework—supplemented by insights from role theory—to our four countries in turn, in each case characterizing past and present research on SG and

exploring ways in which prevailing role concepts enable or inhibit serious consideration of an SG program. As we will show, none of the research conducted in these countries can be accurately described as part of a program as we define it, and such a program is conceivable only in the US at present. In a subsequent comparative analysis, we elaborate on why and how NRCs make a program plausible in the US, but implausible in Germany, China, and Australia unless certain, country-specific conditions are met. A brief conclusion offers recommendations for future research.

## 2 Theoretical background: multiple streams and role theory

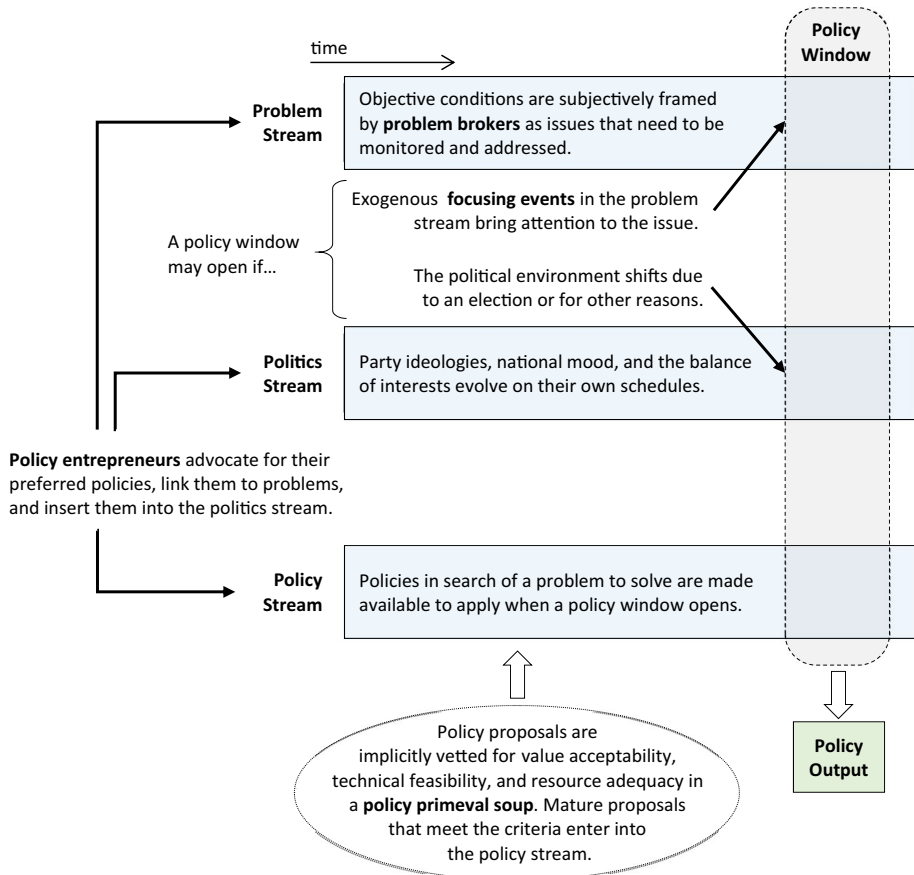
MSA provides a theoretical framework for explaining how policy proposals come to be debated and considered at national levels, with the potential to be implemented as law or policy. Kingdon developed the MSA framework based on his observations of American politics and policy processes, but it has since been applied to national contexts around the world including China (Yao and Cui 2020). MSA conceptualizes the public policy process as consisting of three “streams” of activity oriented toward issues of public concern: the problem stream, the politics stream, and the policy stream. Figure 1 provides an overview of this framework.

The *problem stream* consists of events, issues, and trends that may be defined as “problems” of national importance requiring political attention and potentially a policy response. Not all issues become problems, and not all problems attract attention. Three mechanisms bring attention to problems. First, indicators may signal the perceived severity of a problem; we operationalize indicators as findings from periodic national climate assessments. Second, focusing events are crises, disasters, or other occasions charged with symbolic importance; we operationalize focusing events as extreme weather events. Third, feedback includes formal and informal responses from stakeholders and publics; we operationalize feedback as public concern about climate change.

The *politics stream* is composed of national political actors seeking to advance specific interests, ideas, and values. Actors in the politics stream typically form advocacy coalitions to promote their goals (Mukherjee and Howlett 2015). The flow of the politics stream is shaped by regular, institutionalized processes such as electoral or budget cycles, as well as by less predictable occurrences such as swings in the “national mood” or shifts in ideology; given the emerging status of SG, we operationalize public sentiment in terms of levels of public awareness of the technology. The politics stream also includes less formal but widely accepted elements of the political culture like interest groups; we operationalize interest group politics as dynamics among environmental nongovernmental organizations (ENGOS) regarding SG.

Finally, the *policy stream* contains a multitude of proposals for addressing various public policy issues. These potential solutions inhabit what Kingdon calls a “policy primeval soup”; some ideas may emerge from this primordial soup as serious proposals for national action, but many more will not. Criteria for selection include technical feasibility, cost-effectiveness, congruence with community values, and the degree to which proposals anticipate future constraints. Even if a proposal is selected for serious consideration at the national level, however, there is no assurance that it will be adopted or implemented. We operationalize proposals as program plans.

In addition to policy proposals, the policy stream is closely associated with *policy entrepreneurs* who seek to advance specific proposals by linking them to existing or



**Fig. 1** The Multiple Streams Approach. Source: Felgenhauer, Horton, and Keith 2021

emerging problems. We operationalize policy entrepreneurs as SG research advocates. Policy entrepreneurs take it upon themselves to promote alternatives at the national level by taking advantage of *policy windows* or opportunities for action that stem from changes in either the problem or the politics stream, for example, a natural disaster or national election. When such changes occur and policy windows open, policy entrepreneurs strive to *couple* the streams together. If policy entrepreneurs can successfully couple all three streams, then they may be able to place their preferred policy on the agenda for serious consideration by national political actors.

One persistent criticism of MSA is that it neglects the underlying structural factors that constrain the agenda-setting process (Zahariadis 2014). Mucciaroni summarizes the problem:

Kingdon’s ... model views the role of institutions almost exclusively in situational terms. ... They are identified as “players in the game” and “participants in the streams.” But institutions also make up the topography, the banks and riverbeds that channel and shape participant behavior. They consist of decision-making rules and procedures, roles, authority structures, norms, and routines ... that

have impacts independent of the personal attributes of those who occupy particular positions (1992, 466).

Such institutional structures are “sticky,” and the path dependencies they create mean that “history matters.”

One aspect of this oversight especially relevant to the present analysis relates to the notion of policy viability. Although Kingdon argued that alternative proposals within the policy stream must meet selection criteria to be viable, he neglected to specify the institutional sources of those criteria and hence the determinants of viability. Without specifying which institutions define what is viable, and how they do so, the evolutionary logic operating on the policy primeval soup remains imprecise and the dynamics of the policy stream uncertain.

Recently, Bolukbasi and Yildirim (2022) introduced a framework for considering how institutions shape the key elements of MSA, including the policy stream. They write, “predominant policy principles and paradigms structure the policy stream by filtering the set of available policy solutions. ... for a policy alternative to be viable, it needs to be developed within the boundaries of existing policy principles and paradigms” (Bolukbasi and Yildirim 2022, 10). We argue that NRCs, or “policymakers’ own definitions of the general kinds of decisions, commitments, rules and action suitable to their state, and of the functions, if any, their state should perform on a continuing basis in the international system,” (Holsti 1970, 245–246) constitute one such paradigm.

In essence, role theory applies the sociological concept of a role, that is, a set of behavioral expectations assigned to and inhabited by an individual or collective actor, to understand interactions between states in the international system. Role theorists seek to identify one or more institutionalized role conceptions enacted by states through the language, symbols, and behaviors adopted by or applied to governments. National roles both prescribe and restrict state actions according to shared “scripts” which make international relations more intelligible and more predictable, although there is always scope for misunderstanding.

Role theory and MSA have developed separately from one another, largely because MSA has focused primarily on the domestic arena whereas role theory has focused almost exclusively on international affairs (Jones et al. 2016). We contend, however, that there is significant potential for mutually beneficial engagement between these two research traditions, especially when domestic issues have clear international implications, as is the case with SG. Under such conditions, we maintain that NRCs may be important in terms of their effects on domestic politics and policy processes. As we argue below, the obvious international implications of SG inevitably bring foreign policy considerations into play in the context of ostensibly domestic debates about these prospective technologies, including by filtering research proposals through paradigmatic NRCs as a test of their viability. We operationalize NRCs, within the policy stream, as national role concepts previously identified by role theorists.

In the following four sections, we apply the MSA framework, supplemented with NRCs from role theory to demarcate the bounds of policy viability more clearly, to each of our four case studies. To repeat from earlier, we have selected Germany, China, Australia, and the US because these are the most prominent countries currently active in SG research. Each section will be structured in terms of the problem stream, politics stream, policy stream (including role conceptions), and a prognosis for the future.

## 3 Germany

### 3.1 Problem stream

There is significant German public support for climate action (Forschungsgruppe Wahlen 2020). Public support is bolstered by the government's periodic *Climate Impact and Risk Assessments*, which emphasize the serious risks posed by climate change (UBA 2021). Perhaps surprisingly, there is little evidence that climate and energy policy are driven by extreme weather events (Hake et al. 2015).

In Germany, climate policy is intimately tied to the *Energiewende*, a comprehensive long-term energy transition strategy built mainly on promotion of renewable energy and energy efficiency, which aims to ensure low-carbon energy security including for export-oriented German industry (Ruszel 2017). Increasingly, low-emission hydrogen to decarbonize industry is viewed as key to completing the *Energiewende* (Heering and Gustafson 2021). The *Energiewende* is deeply entrenched and backed by all major parties (except for the far-right Alternative for Germany).

### 3.2 Politics stream

In this context, policies that might undermine the *Energiewende* are consistently marginalized in public debate because considering them would challenge the path dependencies associated with—and call into question the soundness of—the substantial investments made by establishment actors and institutions in the energy transition (Schenuit et al. 2021). It is therefore unsurprising to find little public awareness of and no public appetite for SG (Merk et al. 2019). The media rarely report on it, and most ENGOs, including Friends of the Earth-Germany, Germanwatch, and Heinrich Boell Stiftung, reject it (Schneider 2022).

Given these obstacles and disincentives, political and administrative actors have either avoided the topic or treated it with deep skepticism. The Federal Ministry for the Environment and Consumer Protection, for instance, has limited itself to commissioning reports and workshops conducted by the German Environment Agency. In 2019, the Foreign Office characterized SG implementation as a geopolitical risk (Federal Foreign Office 2019).

In two instances, the German government funded more systematic research. In 2010, the Federal Ministry for Research and Education commissioned an assessment study of “climate engineering” encompassing both SG and carbon removal (Rickels et al. 2011). This was followed in 2013 by a larger but similarly structured six-year, nearly €10 million (\$10 million) National Research Foundation (DFG) Priority Program known as SPP1689, which deliberately avoided research on deployment (Oschlies and Klepper 2016). These efforts were clearly aimed at learning rather than promoting and did not lead to tangible policy discussions, although they did help create considerable SG research expertise in Germany.

### 3.3 Policy stream

SPP1689 did not constitute a program as we define it because its funding amounts were far below the NASEM benchmark, with SG-specific spending equivalent to between two and four percent of recommended levels. No larger plans have been proposed, and

no advocates have stepped up. This is due, in the first instance, to the hegemonic status of the *Energiewende* in German politics and the degree to which an SG program is perceived as potentially undermining it.

At a deeper level, however, the *Energiewende* itself is tied up in a German role conception that is deeply resistant to the policy implications of such a program. For decades, Germany has maintained an NRC as a “civilian power” “built around three central guidelines: ‘never again,’ ‘never alone,’ and ‘politics before force’” (Maull 2015, 409). The civilian power role discourages placing an SG program on the agenda in two ways. First, as part of its role as a civilian power, Germany has acted as a “trading state” to enhance national strength and prosperity and improve its international status, specifically through energy-intensive industrial exports. In a carbon-constrained world, enacting this “trading state role *segment* in the context of its broader role *concept* as a civilian power” (Maull 2015, 514, emphasis original), i.e., continuing to rely on industrial exports as a foundation of economic growth, appears to depend on an accelerated rollout of low-emission hydrogen undertaken both domestically and worldwide. For Germany, maintaining a civilian power role (including as a trading state) is thus now constitutively tied to the success of the *Energiewende*.

Second, the axiomatic status of “never alone” is reflected in an “almost reflexive multilateralism” (Maull 2015, 413) within the German state and society, accompanied by widespread antipathy toward the notion of unilateralism. The close association between SG and the risk of unilateralism—highlighted by the German Foreign Office—seriously diminishes any prospect of a German program. This is evident in, for example, the DFG’s directive that SPP1689 not examine deployment. A proposal for programmatic research into a technology that might enable one state to modify the entire global climate system on its own, while threatening to undercut the energy transition on which continued geo-economic security is assumed to rest, is simply not viable in Germany.

### 3.4 Prognosis

For an SG program to be viewed as a viable proposal in Germany, an external focusing event that challenges expectations associated with the German civilian power role will likely be required. The political shockwaves within Germany triggered by Russia’s invasion of Ukraine are instructive in this regard. Chancellor Olaf Scholz’ proclamation of a *Zeitenwende*, or historic turning point, following the outbreak of war proposed several major policy changes and reversals, including €100 billion (\$100 billion) in new military spending and military support for Ukraine. These proposals, which represent some significant departures from approaches grounded in the concept of civilian power, are now on the agenda.

Similarly, learning that a foreign power was either launching a program or preparing deployment—or had in fact deployed SG—could unsettle emerging understandings about SG in relation to “civilian power” in ways that make a program proposal sufficiently viable to get on the agenda. Such an event might, for instance, encourage some actors to fixate less on the risk of unilateralism and consider possibilities for multilateral governance. Under such conditions, Germany’s civilian power role would dictate that a viable proposal requires partnering with others on SG research, likely facilitated through EU institutions.

## 4 China

### 4.1 Problem stream

In China, most people are aware of climate change and many support stronger public policy (Wang and Zhou 2020). Climate impacts in China are serious, with key risks periodically summarized and publicized in official *National Climate Assessment Reports* (Third National Assessment Report on Climate Change Editorial Committee 2015). Extreme weather events, however, do not appear to influence attention paid to climate change or significantly affect policy (Fan et al. 2018).

Over the past decade, China has undergone a paradigm shift in environmental protection, from a principal focus on pollution control to the prioritization of inclusive green development and “ecological civilization.” Ecological civilization is a set of ideas based on interpretations of Chinese history and philosophy which emphasizes harmony between people and nature (Hansen, Li, and Svarverud 2018). Within the Communist Party, low-carbon development is now synonymous with green development and widely viewed as an exemplar of ecological civilization.

### 4.2 Politics stream

Public awareness of SG in China is assumed to be low, while the scope for ENGO activity in the country is limited (Visschers et al. 2017). The political system grants scientists some leeway to pursue curiosity-driven research so long as it is compatible with party-state interests. In this regard, a subset of Chinese climate experts secured modest government funding for three research projects. The most prominent of them, titled “Mechanism and Impact of Geoengineering,” was supported by the Ministry of Science and Technology (MOST) between 2015 and 2019 at a cost of 14.4 million RMB (\$2.2 million). It focused on three themes: understanding physical mechanisms, modeling climate impacts, and international governance. These were selected based on discussions between the funding agency and participating scholars and reflected a collective desire to address the modeling and governance aspects of SG while avoiding more controversial deployment research (Cao et al. 2015).<sup>1</sup> The National Natural Science Foundation of China funded two smaller projects (each less than 1 million RMB), one on impacts on permafrost and the other on the ocean carbon cycle.<sup>2</sup>

Support for this research was motivated by a desire to catch up to perceived advances in the West (Chen 2017). Uncertainties and risks associated with SG as well as ethical concerns make Chinese scholars unwilling to advocate research involving outdoor experiments and deployment technology (Moore et al. 2016). Neither national research directors nor their superiors in the newly established Strategic Consultation and Comprehensive Review Committee on science, technology, and innovation (led by the MOST) have expressed any interest in establishing or funding a Chinese program (Cao et al. 2018).

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<sup>1</sup> Based on personal communication with project lead John Moore.

<sup>2</sup> Relevant information was retrieved from the projects database of the National Natural Science Foundation of China (<https://kd.nsfc.gov.cn>) on 26 March 2023.



### 4.3 Policy stream

Funding for “Mechanism and Impact of Geoengineering” totaled a mere one to two percent of the level recommended by NASEM. No program plans have been formulated in China, nor have any program advocates come forward. This accords with the high levels of risk aversion known to pervade Chinese funding bodies, which limits support for novel or risky research (Qiu 2014).

Related to this, Chinese political culture is characterized by norms of conflict avoidance and stability maintenance (Shi 2001). This imperative is evident in China’s two NRCs: “*tianxia*” (“all under heaven”) and “internal development” (Demirduzen and Thies 2021). The influential concept of *tianxia* holds that “China (the center country) should be selfless and caring for others in a harmonious world where mutual gain is significant” (Demirduzen and Thies 2021, 10). Separately, when enacting an internal development role, “China sets its national agenda and foreign policy as a means for its own internal economic development, needs, and social well-being” (Demirduzen and Thies 2021, 10). Together, *tianxia* and internal development emphasize harmony and (relative) passivity while discouraging policies that might be perceived as disruptive. Evidence indicates that a cross-factional consensus on the primacy of *tianxia* and internal development prevails at the national level in China (Demirduzen and Thies 2021).

This may seem at odds with an apparent pattern of increasingly assertive Chinese behaviors, for example, in the South China Sea. Close examination of more aggressive episodes in China’s recent history, however, shows that these are typically instances of “reactive assertiveness,” that is, of China reacting to perceived threats to its “core interests” of state sovereignty, national security, and territorial integrity (Kleine-Ahlbrandt 2012). Other noncore (“important” or “secondary”) issues do not appear to trigger confrontational behaviors (Danner 2018). Reactive assertiveness may be regarded as consistent with *tianxia* and internal development role concepts insofar as threats to core interests are understood as disruptions to a harmonious order whose restoration may require strong measures (Buzan 2014). Such measures may be highly visible, yet they are anomalous in relation to the primarily status quo orientation of China’s NRCs.

Chinese leaders likely understand that establishing an SG program is liable to trigger fears about the possibility of unilateral action, with destabilizing effects on international politics. This makes any such proposal nonviable for a country which under normal circumstances is chiefly concerned with preserving conditions favorable to continued growth and development (Goldstein 2020). The apparent lack of interest in expanding research on the part of relevant elements of a party-state predisposed toward maintaining stability thus aligns with expectations.

### 4.4 Prognosis

For an SG program to be regarded as a viable proposal in China, a perceived provocation from outside the country will likely be required. In the Chinese context, the logic of reactive assertiveness dictates that an external disturbance sufficient to trigger serious consideration of a proposal otherwise disallowed by prevailing *tianxia* and internal development role conceptions must be perceived as touching on core national interests. Researchers increasingly recognize that China regards status as a core interest (Murray 2018). Insofar as the launch of a US program would be viewed as enhancing American

prestige, such a move by the US could function to enhance the viability of a proposed Chinese program.

An American program would have a high profile and serve to reinforce that country's superpower status. Under such circumstances, Chinese leaders, especially those responsible for steering China's national science and technology system, would probably feel a need to respond in kind, as they have on comparable issues like space missions and R&D megaprojects (Gilady 2018). The pressure to react to a US program would likely be stronger than earlier desires to catch up with Western research and may be sufficient to overcome latent resistance to potentially destabilizing policy proposals.

## 5 Australia

### 5.1 Problem stream

Until recently, public concern about climate change in Australia had been persistent but insufficient to move political leaders (Neumann et al. 2022). Biennial *State of the Climate* reports released by the government documented growing climate risks but failed to spur more aggressive measures (BOM and CSIRO 2020). Likewise, the occurrence of extreme events did not result in more ambitious policies (Jetten et al. 2021). In 2022, however, the Australian Labor Party won a national election after campaigning on a platform of stronger climate action; early signs suggest this will significantly alter national policy.

Despite historically weak action on emission reductions, the national government has made substantial investments in adaptation. The Great Barrier Reef (GBR) off the Queensland coast, a national icon and regional economic engine threatened by climate-related warming of waters and associated coral bleaching, has been a particular focus of adaptation research and action.

### 5.2 Politics stream

While public awareness of SG in Australia appears low and ENGOs have neglected to take up the issue, the fate of the GBR garners widespread attention. In 2016–17, back-to-back coral bleaching events affecting two-thirds of the GBR confronted the national and Queensland state governments with the potential loss of an iconic World Heritage-listed ecosystem, economic damage to a multibillion dollar per year tourism industry, and national and international criticism.

In response, authorities undertook three related steps. First, in 2017 the two governments collaborated on a *Reef Blueprint for Resilience* focused on restoring degraded reefs and trialing different techniques to promote adaptation to warming waters (GBRMPA 2017). Second, they committed more than AUD\$500 million (\$324 million) for research and implementation of Reef protection measures, including initial research on marine cloud brightening (MCB) (framed as adaptation rather than SG) (Turnbull, Cash, and Frydenberg 2018).<sup>3</sup> In 2020–2021, AUD\$4.8 million (\$3.4 million) was directed toward cooling and shading research (including on MCB) (Reef Trust Partnership 2020). Third,

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<sup>3</sup> MCB would involve spraying seawater into low-lying clouds to increase their reflectivity and cool underlying waters.

the GBR Marine Park Authority authorized the first field test of MCB delivery equipment in 2020, with a larger test conducted in 2021. Operational tests of MCB have not yet been carried out.

### 5.3 Policy stream

Clearly, GBR-focused MCB research, funding for which is between two and four times greater than the annual budget recommendations made by NASEM, will advance SG research. MCB research conducted as part of a GBR protection program, however, is not the same as a research program dedicated to SG. The research questions, methods, and outputs—and hence designs—of a dedicated, compared to a nondedicated, program would be substantively different. For example, a dedicated program investigating MCB would focus on aerosol-cloud interactions and would direct research toward regions where conditions appear most appropriate for interventions, which would exclude Australasia (NASEM 2021). By contrast, current and planned research in Australia is heavily focused on developing hardware for application over the GBR, an area recognized as suboptimal for MCB (Mead et al. 2019).

No dedicated Australian programs have been proposed to date, nor have any potential policy entrepreneurs stepped forward. This is not surprising given that Australian scientists have a long tradition of deep collaboration with their US counterparts, particularly following the Second World War, to the point that such “collaboration was built into the Australian system” (Harris 2019). Not coincidentally, close coordination with the US is an essential element of Australia’s NRC of “faithful US ally,” in which “a government makes a specific commitment to support the policies of [the US] government” (Holsti 1970, 267; see Thies 2019). In this role, Australia generally takes its cues from the US when it comes to significant issues in world politics, unless there is a clear and compelling national interest in acting otherwise. The country’s proclivity to defer to the US in such matters, exemplified by the recent announcement of the AUKUS security pact, is deeply ingrained in public and elite opinion and in all major political parties and institutions (Bisley 2013). As a follower rather than a leader on global issues, initiating a research program on a technology intended to alter the course of the global climate system is not a viable policy option for Australia.

### 5.4 Prognosis

As in previous cases, for a dedicated program to be considered a viable proposal in Australia, an external event seems necessary. Australia’s role as a faithful US ally—a role that clearly extends beyond defense—would appear to make an Australian proposal contingent on the initiation of an American program. The history of the Australian space program is illuminating in this respect: the Australian government has partnered with the National Aeronautics and Space Administration (NASA) since its creation in 1958 but established its own space agency only in 2018, with the understanding that it would continue to engage primarily with NASA (Harris 2019). This pattern is not atypical.

Provided an American SG program was launched, no fundamental barriers appear to preclude serious consideration of an Australian one. Australia’s role conception, however, would require that a proposed program link to an American program. As argued above, this program would also look different from current GBR-focused MCB research activities.

## 6 The United States

### 6.1 Problem stream

Surveys show high levels of awareness of and concern about climate change among Americans (Tyson and Kennedy 2020). Further, the US government's quadrennial *National Climate Assessments* consistently underscore the risks posed by climate change (USGCRP 2017). Even after repeated destructive extreme weather events, however, strong national climate policies were lacking until the signing into law of the 2022 Inflation Reduction Act, which will make substantial investments in climate and energy security through tax credits and subsidies.

### 6.2 Politics stream

The US public is mostly unaware of SG (Mahajan et al. 2019). The federal government, however, has slowly started to engage the issue. Since 2020, the National Oceanic and Atmospheric Administration has received \$22 million for its Earth's Radiation Budget research initiative focused on enhancing stratospheric observational and modeling capabilities, establishing a baseline of stratospheric data, and improving understanding of marine clouds. In its 2021 report, NASEM proposed that the US Global Change Research Program oversee a new SG program with funding of \$100–\$200 million over the first five years to support a range of natural and social science investigations including small-scale outdoor field experiments (NASEM 2021). The White House Office of Science and Technology Policy (OSTP) is currently developing a five-year SG research framework and plan (Temple, 2022).

Although no ENGOs support SG deployment, their views on research vary. “Pragmatist” groups including the Environmental Defense Fund, Natural Resources Defense Council, and Union of Concerned Scientists conditionally support SG research including small-scale outdoor experiments (CAN 2019). In contrast, “purist” ENGOs such as Friends of the Earth-US and 350.org oppose research (Felgenhauer et al. 2021).

### 6.3 Policy stream

Since it was proposed in 2021, NASEM's program plan has figured prominently in policy discussions. As noted, OSTP is currently preparing its own proposal. SilverLining, a relatively new group advocating for expanded research on SG, has also put forward a plan (Wanser et al. 2023). At present, SilverLining stands as the only obvious candidate to play the role of policy entrepreneur, but others could emerge.

Unlike the previous three cases, the viability of such proposals is not negated by the American postwar NRC of “leader” (Friedrichs 2020). A leader is a complex role consisting of four “auxiliary roles”: “an initiator, an agenda setter, and a mediator component as well as a representative function” (Harnisch 2016, 6). America's roles as initiator and agenda setter specifically enable the types of policy processes that would be integral to weighing whether to pursue an SG program. As a leader, the US is unique among the countries under consideration in its consistent and longstanding willingness to mount international campaigns, push frontiers, and shoulder responsibilities on behalf of others. Such propensities are deeply inscribed in American political traditions, institutions, and ideologies.

## 6.4 Prognosis

So far, no policy windows which might allow a policy entrepreneur like SilverLining to place a program on the US agenda have opened, yet such an event is hardly inconceivable. What is lacking now is an advocacy coalition actively supporting the creation of an SG program. The formation of a coalition will depend on whether sympathetic actors coalesce around pragmatist ENGOs or other key players in climate policy. With a functioning advocacy coalition in place, and when the timing is right, there should be no obstacles to an effective policy entrepreneur getting a program on the US agenda.

## 7 Results and discussion

The results of these case studies are summarized in Table 1. Neither problem streams nor politics streams vary across cases in ways that account for different national developments and possible future trajectories. In none of the four countries did extreme weather events lead to major shifts in climate policy. Policy streams, however, do vary in important respects which seem to explain current developments in these countries and to identify necessary conditions for change. Specifically, prevailing role conceptions shape policy landscapes in ways that determine whether SG program proposals are viable. In Germany, the civilian power role promotes a policy orientation uncondusive to SG. In China, *tianxia* and internal development roles set boundaries for acceptable behavior which under normal circumstances exclude serious consideration of SG. In Australia, the faithful US ally role specifies conditions under which a proposal is viable. In the US, the leader role poses no obstacles to policy viability.

At the theoretical level, these results suggest that NRCs can affect agenda setting in two ways. First, NRCs promote overarching policy orientations which make specific policy proposals more or less viable. Germany's civilian power NRC makes any proposal for a German program nonviable at present. In contrast, a US proposal appears unproblematic in the context of America's global leadership role. Second, NRCs may prescribe specific conditions under which policy proposals are viable. China's NRCs delimit what is viable under normal circumstances—which does not include proposals for programmatic research on SG—while implicitly recognizing that exceptional circumstances—perceived threats to core national interests—may alter this calculus. And Australia's faithful US ally role specifies that for an Australian proposal to be viable it must be linked to an American program.

These results also suggest three ways in which events occurring outside a country can interact with NRCs to alter policy viability. First, an external shock might challenge conventional understandings conditioned by dominant role conceptions, allowing for reinterpretations or revised assumptions that make viable what was previously nonviable. This is conceivable, for instance, in the German case. Second, an external occurrence might signal that conditions for viability have changed; this seems plausible in the case of China. And third, an external development might constitute the change necessary for a proposal to become viable, as can be imagined in the Australian case.

In all three of these cases, the present analysis reinforces the potential importance of developments outside of a country in influencing agenda setting within national borders. Because it is primarily focused on domestic politics and policy, there is a risk that analyses carried out using the MSA framework overlook international and transnational trends and

**Table 1** Case study results summary

Variables	Germany	China	Australia	US
Problem stream	Assessment findings ( <i>indicators</i> )	Climate risks high	Climate risks high	Climate risks high
	Extreme weather ( <i>focusing events</i> )	No effect on climate policy	No effect on climate policy	No effect on climate policy
	Public concern about climate ( <i>feedback</i> )	Serious	Serious	Serious
Politics stream	Public awareness of SG ( <i>public sentiment</i> )	Low	Low	Low
	Environmental NGOs ( <i>interest groups</i> )	Opposed	Unengaged	“Pragmatists” vs. “purists”
Policy stream	Programmatic plans ( <i>proposals</i> )	None	None	NASEM, SilverLining
	Research advocates ( <i>policy entrepreneurs</i> )	None	None	SilverLining
	NRC ( <i>viability</i> )	“Civilian power”	“Faithful US ally”	“Leader”
Prognosis	Requirement for agenda setting	US program (alter orientation)	US program (meet viability condition)	Advocacy coalition formation

events that could influence national policy processes. This risk is particularly acute when it comes to issues which are inherently international such as climate change and SG.

From a policy perspective, this analysis underscores what appears to be the critical importance of US policy processes for agenda setting in other countries, at least when it comes to SG. In different ways, the future of programmatic SG research in the US seems to hold the key to similar possibilities elsewhere. The adoption of such a proposal appears to be a necessary condition for comparable developments in Australia. Given contemporary global power dynamics, this also seems necessary for China to move in a similar direction. And given the scarcity of countries active in this field, the initiation of a US program also appears necessary for Germany to contemplate its own effort. International dependence on US agenda setting in this instance thus renders advocacy coalition formation and the broader politics of SG in the US especially influential in shaping the global trajectory of this technology.

## 8 Conclusion

We offer three recommendations for future research inspired by the present analysis. First, we encourage analysts employing MSA to engage substantively with role theory. As noted earlier, a recognized limitation of MSA is its inattention to structural constraints on agenda setting, including policy viability. We believe the results above demonstrate the potential for treating NRCs as institutional paradigms that help define what is viable within the policy stream.

Second, we also encourage role theorists to engage with MSA. In today's world, role theory could profit from considering the role of NRCs in national agenda-setting processes with international significance. Engaging with the MSA framework would also equip role theorists with an arguably more developed conceptual apparatus, enabling them to address criticisms that role theory lacks analytical rigor (Thies 2010).

Third, as stressed at the outset, the present analysis is exploratory. We regard it as successful in providing guidance on probable—and improbable—near-term policy pathways, yet the propositions developed here require further elaboration and rigorous testing before they can be considered as robust contributions to social science theory building. Nevertheless, in a context where comparative analysis has played a minimal role to date, we believe our findings can help sharpen emerging policy debates in ways that are relevant and constructive.

**Author contribution** All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by all authors. The first draft of the manuscript was written by Horton, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

**Data availability** No datasets were used in the production of this manuscript.

## Declarations

**Ethics approval and consent to participate** This research did not involve humans or animals. All authors agree with the content, give explicit consent to submit, and obtained consent from the responsible authorities at the institutes/organizations where the work was carried out.

**Competing interests** The authors declare no competing interests.

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