



ARTICLE



<https://doi.org/10.1057/s41599-022-01213-5>

OPEN

Legitimacy and procedural justice: how might stratospheric aerosol injection function in the public interest?

Marco Grasso ¹ 

The success of stratospheric aerosol injection (SAI) in limiting global heating requires the inclusion and maintenance of the political ideals of legitimacy and procedural justice. Without them, the prospects are slim that this institution can be developed and operated in the public interest in such a way that it will protect and promote social well-being by minimising climate-related harm. Long-term legitimacy and procedural justice are crucial to several sensitive features of SAI. They relate to openness, inclusivity, and independence in dealing both with external issues of concern to stakeholders representing the general public and with internal issues concerning agents directly involved in SAI. This article begins by outlining notions of legitimacy and procedural justice and the criteria appropriate for SAI. Then it investigates how the indications provided by the related standards and the consequent morally sound governance options advanced might warrant that SAI is not distorted in such ways that it serves the vested interests of private parties. Finally, the article outlines two recommendations for ensuring that legitimacy and procedural justice in SAI are achieved and maintained over time, so that it can work continuously in the public interest.

¹Università degli Studi di Milano-Bicocca, Milano, Italy. email: marco.grasso@unimib.it

Introduction

Solar geoengineering aims to lessen the amount of solar energy reaching the Earth in order to reduce regional or global temperatures (Caldeira et al., 2013). The article's arguments refer to stratospheric aerosol injection (SAI), perhaps the most debated approach of solar geoengineering. SAI imitates the cooling effect of a volcanic eruption through the dispersion of inorganic particles—e.g., sulfates or calcium carbonate—in the lower stratosphere. The article will focus on this approach for two reasons: SAI's high leverage—its capacity to exert great influence over the climate system from relatively limited technological and economic inputs—and its potential for rapid deployment (Zürn and Schäfer, 2013). These features, and the intrinsic challenges it poses, make an examination of SAI very instructive for a greater overall understanding of solar geoengineering.

It should be specified that we believe that in a *sane* world SAI would be an unlikely option, given the many unknowns and unknow unknowns associated to 'hacking the planet' (Pierrehumbert, 2017). Unfortunately, we are living in irrational times in which the impending climate crisis is not addressed meaningfully, and persistent market distortions and governance and policy failures strengthen carbon lock-ins (Grasso, 2022). Therefore, SAI could acquire urgency at very short notice: hence the importance of reflecting in advance on how it could ultimately be beneficial to humanity. The objective of this article—to illustrate a way to provide SAI with long-term legitimacy and procedural justice, in order to enhance its prospects of being developed and carried out in the public interest—is exactly inscribable in this broad perspective.

SAI is considered here as an *institution* for researching and deploying approaches to reducing temperatures by diminishing absorbed solar energy. Drawing on insights from neo-institutional theory, evolutionary economics, and economic sociology institutions are understood as coordinated patterns of behaviour organised through formal and informal schemes of norms, procedures, rules, mechanisms, structures, and instruments (Buchanan, 2010) with which SAI can be governed in a long-term, harmonised way. All of this is determined by a variety of technological inputs, regulations, policies, markets, organisations, and networks. Institution, therefore, means in this perspective both the processes involved and the outcomes generated. This brings the advantage that the contentious distinction between SAI research and deployment (Jinnah et al., 2018) can be ignored as non-relevant here because, as an institution, SAI includes research, development, experimentation, and gradual deployment. SAI is, therefore, the locus of legitimate and procedurally just governance that coordinates the organised behaviours of different agents over different jurisdictions and time periods. In brief, SAI as an institution—and not, for example, any particular SAI research project—is the object of this analysis of legitimacy and procedural justice.

The temperature of the planet has been climbing for the past two centuries, but since the post-war boom in both consumption and population it has rocketed (Bova et al., 2021; Kaufman et al., 2020). This increase of energy in the atmosphere is provoking a surge of extreme weather events, in terms of both frequency and intensity. As the climate-related disasters of the summer of 2021—virtually impossible without climate change (Philip et al., 2021)—testify, nowhere in the world is safe any longer: humanity is experiencing a global climate emergency (Bradshaw et al., 2021; IPCC, 2022; Lenton et al., 2019), whose probability of further worsening has increased (Fischer et al., 2021). Over three billion people could be trapped in 'near unlivable' heat by 2070 (Xu et al., 2020), and the tropics, home to 40% of the global population, will become 'uninhabitable' by 2050 (Zhang et al., 2021) if carbon emissions do not decrease dramatically in a short time span.

Unfortunately, the current pattern of decarbonisation of global socio-economic systems is inadequate to tackle such impending climate crisis (Masson-Delmotte et al., 2021). This might well make necessary the use at short notice of (as yet) uncertain and controversial approaches such as SAI—in addition to other, complementary strategies (Keith, 2013), in particular mitigation and negative emissions technologies (NET) (e.g., MacMartin et al., 2018; Reynolds, 2022). At the same time, the inclusion of the political properties—or *ideals* (Pettit, 2012)—of legitimacy and procedural justice in SAI is crucial for investigating the key features of this institution's governance (SRMGI, 2011; Bodle et al., 2014; Schäfer et al., 2015; Frumhoff and Stephens, 2018; Callies, 2019a, b).

Given its complexity and its many uncertainties, there is clearly a need for normative analyses of SAI. Numerous works have already examined its normative desiderata, such as effectiveness (e.g., Buck et al., 2020), efficiency (e.g., Moriyama et al., 2017), distributive justice (e.g., Svoboda, 2017), and political feasibility (e.g., Grasso, 2019). Others have explored its legitimacy—as clarified in the following sections—but with different perspectives, notions, and scopes from the ones employed in this article. Nor do more than a few works focus on its procedural justice; one notable exception is Callies (2018, 2019a), but his work regards procedural justice as only one of a series of criteria for judging the legitimacy of solar geoengineering.

The other main rationale—possibly the most important—for further scrutiny of legitimacy and procedural justice in SAI is that these two political properties, given the permeability of this family of approaches to exogenous interferences (Szczyszynski et al., 2013; Zürn and Schäfer, 2013), are critical to SAI's ability to work in the public interest and generate stable widespread support amongst civil society.

Additionally, SAI has become a major focus of legitimation and de-legitimation, with the policy and academic literature divided into two camps. Those who support it, argue that its effectiveness and efficiency far outweigh any possible illegitimacy and injustice, while those who are more sceptical argue that the high levels of risk and the distributional concerns involved mean it should not be countenanced.

This article investigates the notions of legitimacy and procedural justice that SAI should embrace if it is to obtain and maintain the long-term capacity to work in the public interest to limit global heating. After clarifying why legitimacy and procedural justice are critical for SAI, the article outlines appropriate meanings for these political properties, paying particular attention to the sensitive issues of openness, inclusiveness, and independence. It goes on to specify the suitable legitimacy and procedural justice criteria and standards as well as consequent morally sound governance options, and finally to conclude by outlining two recommendations by which legitimacy and procedural justice can be achieved and maintained over time.

The importance of legitimacy and procedural justice in SAI

SAI is a high leverage institution that could be called into play at relatively short notice, as said. It is, however, hampered by a lack of factual knowledge and fraught by physical and socio-political issues (Halstead, 2018) that pose not only moral hazards (McLaren, 2016; Tsipiras and Grant, 2022) and governance problems (Horton and Reynolds, 2016; Pasztor et al., 2017; Reynolds, 2019; McLaren and Corry, 2021), but even fears that it is ungovernable (Talberg et al., 2018; Dove et al., 2021).

One major challenge is to avoid SAI being outsourced or *captured* by elites, who could manipulate decision-making processes in their own interests (Hamilton, 2013). These elites consist

generally of large companies (e.g., fossil fuel, chemical, hi-tech, aerospace, etc.), industry representatives, political authorities, governance institutions, technocrats, bureaucrats, international managerial groups, and the financial system (Szerszynski et al., 2013; Winsberg, 2021).

One promising way to minimise this danger is to ensure that legitimacy and procedural justice are part of SAI, as implied by the conclusions of prior studies (SRMGI, 2011; Morrow et al., 2013; Zürn and Schäfer, 2013; Bodle et al., 2014; Schäfer et al., 2015; Frumhoff and Stephens, 2018; Callies, 2018, 2019a; Grasso, 2019; Morrow, 2020). They are the most appropriate political properties for ensuring that this institution works in the public interest, as they necessitate, per se, openness, inclusiveness, and independence. As other authoritative works emphasise, implicitly or explicitly, (e.g., Bodle et al., 2014; Schäfer et al., 2015; Chhetri et al., 2018; Pasztor et al., 2019), the inclusion of these ideals in SAI will help to reduce the risk that it is exploited by private vested interests taking advantage of dubious governing structures (Zürn and Schäfer, 2013), asymmetries of power and knowledge, deceit, disinformation, or other malpractices. Openness, inclusiveness, and independence should be sought in SAI's external relationships—where they are a matter of legitimacy—with stakeholders, e.g., decision-makers, social movements, epistemic communities, professional networks, and experts from techno-scientific groups (Hamilton, 2013). Procedural justice applies to internal issues, concerning which agents, e.g., political authorities, companies, scientists, managers and workers, investors, etc., should be involved in SAI and the manner of their participation (Schäfer et al., 2015).

In practical terms, international law certainly involves provisions—generally based on principles of precaution, liability, and no harm—that make the unilateral deployment of SAI extremely difficult (Brent, 2021). However, the inclusion of legitimacy and procedural justice in SAI would further limit the above-mentioned risk of capture for two reasons: first, bearing in mind the institutional understanding of SAI adopted, these political properties would exclude the unilateral manipulation of SAI research too; second, and perhaps more substantially, while legal provisions simply prevent SAI to be diverted to the vested interest, legitimacy and procedural justice shape from the beginning the development of SAI to actively aim at the public interest.

Some scholars (e.g., Bodansky, 2013), however, discourage the establishment of new governance systems for solar geoengineering, citing the potential problematic co-existence of their decision-making authority with the current relevant ones and their likely burdensomeness. They argue that the legal mandates and the political capabilities required to manage solar geoengineering appropriately already exist, including joint governance structures, preferably under the aegis of the United Nations. Others, conversely, suggest that new governance systems are needed for the rapid development of solar geoengineering research. With regard to the argument of this article, these latter scholars outline general frameworks or proposals for shaping sub-state (e.g., Jinnah et al., 2018), international (e.g., Horton et al., 2018) or polycentric and spontaneous systems (e.g., Nicholson et al., 2018; Talberg et al., 2018), as well as global deliberative bodies to lend solar geoengineering legitimacy and/or authority (e.g., Morrow et al., 2013; Parson, 2017; Jinnah et al., 2019).

This article does not enter the controversy but argues that legitimacy and procedural justice should be endogenous to SAI, rather than granted, or not, by onerous external governance systems. The parsimony allowed by this novel *locus* of legitimacy and procedural justice affords us the opportunity to explore how SAI's feasibility and its ability to work in the public interest can be enhanced.

We need to clarify our use of *public interest*, of which, despite the pervasiveness and influence of the term, there is no generally

agreed definition. In democratic societies, it is usually perceived as allowing public action to be judged, and to serve as its guide and scrutiniser (Downs, 1962). Accordingly, this article will use *public interest* to mean the yardstick to measure whether, and to what extent, public actions benefit society as a whole, rather than just specific groups (Steffek, 2015). In particular, with regard to the current climate crisis, public interest relates to SAI's long-term objective of protecting and promoting social well-being through the minimisation of climate-related harm.

Background issues and the criteria of legitimacy and procedural justice in SAI

Both legitimacy and procedural justice offer normative justification to institutions. They are closely intertwined, but they focus on different elements (Rawls, 2005, pp. 427–429; Buchanan and Keohane, 2006; Buchanan, 2010): legitimacy concerns the institution itself, whereas procedural justice relates to how its decisions are made (Page, 2012). Thus, it is useful to separate the analyses of legitimacy and procedural justice.

To articulate legitimacy and procedural justice in such a way as to make them achievable in the long term, it is worthwhile defining the nature and objectives of *criteria* and *standards* with regards to SAI.

Criteria should be understood as the long-term moral yardsticks that SAI should take into consideration and gauge its actions against. Criteria will, therefore, contribute to its acting consistently with its objectives, avoiding its being used against the interests of the public. They help interpret the moral landscape in which SAI operates, without necessarily mandating any particular direction to be taken.

Standards are moral references that should inform an institution's functioning, consistent with the general context set by criteria. A standard provides more concrete—although not case-specific—indications and can suggest governance options for organising SAI consistently with the related criterion. The following section will highlight the standards of legitimacy and procedural justice in SAI. Put forward some of the more relevant morally sound governance options entailed by their indications and the related 'real world' examples.

It should be noted that the milieu of reference for criteria and standards are mainly of a moral character. On the one hand, legitimacy and procedural justice are eminently moral constructs which aim at increasing the overall morality of SAI; on the other hand, SAI remains morally contentious, and its almost endless moral implications vigorously challenge dominant beliefs and attitudes (Baatz et al., 2016). These two considerations provide the rationale for framing the analysis of criteria and standards in moral terms.

Additionally, criteria and standards work at different levels. Criteria are broad and so it can be difficult to draw reliable conclusions as to how they can be satisfied. Standards, on the other hand, can be expressed in narrower, more understandable ways, which makes them crucial for assessing the overall legitimacy and procedural justice of SAI. They operate, therefore, as proxies that can either be met or not, determining whether the specified criteria are satisfied: they provide indications for SAI to act, consistently with the criteria, in the public interest by giving more practical implications.

For example, it might not be possible to recognise whether an SAI enterprise is properly managed. But as long as SAI is shaped so as to avoid excessive burdens on more vulnerable people, is transparent, guarantees the fair involvement of agents, and ensures access to accurate knowledge about its functioning, it should be possible to determine whether such an SAI enterprise is being operated in a legitimate and procedurally just way and catering to the public interest.

Finally, although the criteria and (to an extent) the standards described below are taken from the general literature on legitimacy and procedural justice, one of the main original and novel contributions of this article is that it specifically shapes and develops them to maximise the extent to which SAI functions in the public interest. Indeed, as we repeatedly emphasise, there is a significant risk that this institution will be captured by elites and forced to work in favour of private/vested interests. The criteria and standards that SAI should pursue are meant to involve different yet complementary constituencies, given the diverse normative scope of legitimacy and procedural justice: the former focuses on how institutions should connect externally and the latter on how they should operate internally.

The criteria and standards of legitimacy relate to external issues concerning its openness, inclusivity and independence and address a broad number of stakeholders representative of the general public—as said decision-makers, social movements, epistemic communities, professional networks, and experts from techno-scientific groups, including indirect and contrarian perspectives. Those of procedural justice concern internal issues and are targeted at fewer involved agents: those directly engaged in SAI—as anticipated, political authorities, companies, scientists, managers and workers, investors, etc.—and the manner of their participation. This inclusiveness provides further reason to believe that the criteria and standard developed will maximise the likelihood of SAI working in the public interest.

This section scrutinises criteria of legitimacy and procedural justice and the following one deals with the analysis of the related standards.

Criteria of Legitimacy. The general reference is to normative legitimacy, as it offers a benchmark of the acceptability or justification of institutions. The notion that is required of normative legitimacy applies to all types of institutions, regardless of power, authority, and coercion, which are the cornerstones of its usual *right to rule* understanding (Buchanan, 2013) and traditionally refers to states. The adopted notion instead also takes into account the purpose of the institution to which it is applied (Adams, 2020): SAI may not wield any power or authority, nor apply coercion, and its legitimacy may, for example, concern the systematic coordination of different stakeholders over different jurisdictions.

This article argues for a view of normative legitimacy quite different from the descriptive one commonly used by other studies on solar geoengineering (e.g., Frumhoff and Stephens, 2018; Jinnah et al., 2018), which maintain that determinants of legitimacy cannot be established a priori from a *checklist* (Bernstein, 2011, p. 42), that is to say, normatively. Rather they can only be developed positively, based on the acceptance of those involved. Here, though, we argue that normative legitimacy is indispensable for institutions to gain moral-based support—not only strategic or self-interested (Buchanan and Keohane, 2006) or coercion-based backing (Hurrell, 2005; Buchanan, 2013)—and specifically to foster an open, inclusive, and independent SAI. It is also true that, given the obvious interdependence of the two notions of legitimacy (Clark, 2005), if an institution is normatively legitimate, it would also see its descriptive (or sociological) legitimacy simultaneously enhanced (Buchanan and Keohane, 2006, p. 436).

The distinctive features of SAI, such as its multifariousness and compositeness, its current state of inexistence and unknowability, its general non-coercive role, its scalability and its capturability, make it difficult to nominate a suitable notion of normative legitimacy from among those already developed. An appropriate one seems to be that of *output legitimacy* as framed and analysed

by Steffek (2015), based on Fritz Scharpf's seminal works on *input and output legitimacy* (Scharpf, 1970, 1999). It concerns the design of institutions whose output serves the public interest by benefitting people and safeguarding their rights. This emphasis on serving the public interest is also stressed by Zürn and Stephen (2010, p. 94), who argue that any "... justification [of legitimacy] is an appeal to the common interest of the collective."

Although universal criteria for the legitimacy of institutions do not exist it is possible to determine suitable ones by drawing on the relevant literature (Buchanan and Keohane, 2006; Zürn and Stephen, 2010; Keohane, 2011; Buchanan, 2013, and to make specific reference to solar geoengineering legitimacy Morrow et al., 2013; Callies 2018, 2019a). Given its *functional* nature, SAI should abide by two criteria that specifically refer to external issues, i.e., to the relationship of this institution with stakeholders representative of the general public. The first requires that SAI avoid inflicting serious injustices; the second compels SAI to provide sound information for dealing with normative disagreement and uncertainty (Buchanan and Keohane, 2006).

If the SAI's choices were to cause serious injustice, it would be falling short of its mandate to protect the public interest by promoting social well-being. Similarly, if it failed to produce and share reliable information continuously, it would become opaque, which would also hinder the pursuit of the public interest by making it easier for unaccountable elites to manipulate its operations in their interests.

For the sake of simplicity, we will refer to this normative notion of output legitimacy simply as *legitimacy*. The two criteria of legitimacy appropriate for SAI introduced above are:

- *avoidance of serious injustice;*
- *provision of reliable information.*

With regard to the *avoidance of serious injustice* criterion the SAI's first duty is to prioritise more vulnerable people. There is ample evidence of the potential consequences of SAI on the more vulnerable and of the importance of the involvement of stakeholders who represent them in SAI decisional processes. Their early engagement is essential to ensuring that humanitarian considerations taking into account the particular needs, priorities, and opportunities of the more vulnerable are integrated into this institution (Suarez and van Aalst, 2017), especially given the existence of predatory behaviour by elites. In this context it is useful to refer to a *starting point* notion of vulnerability, also termed *social vulnerability* (Kelly and Adger, 2000). In a broader perspective, the ethical imperative to put the most vulnerable first is very widely accepted, including in relation to the climate crisis where particular concern is felt for weaker and more socially vulnerable agents. Furthermore, more socially vulnerable people are more likely to be exposed to the possible harm—unknown in magnitude and distribution, but potentially significant—associated with SAI; universal principles of justice state, however, that all people—and, indeed, the more vulnerable—have a moral right not to suffer harm (Shue, 2015).

The criterion of *provision of reliable information* refers to SAI's need to maintain public trust in the long term, which is not easy, given the complexity and uncertainty of this institution. Channels need to be established for transmitting reliable information to stakeholders in order to avoid disagreement and/or facilitate reconciliation (Winsberg, 2021). As well as the risk of appropriation, its mode of operation might become quasi-autocratic, behind closed and impenetrable doors, hidden from the gaze of society and stakeholders. This, indeed, has happened within other climate institutions, for instance—to some degree—with the flexibility mechanisms of the Kyoto Protocol (Sabel and Victor, 2017). So, in order to combat these risks and to dampen the

threat that SAI serves vested interests—and indeed to magnify its ability to work in the public interest despite external interference—it needs to produce accurate information, despite the fact that the only undeniable trait of this institution, in current circumstances, is uncertainty. Dealing with uncertainty requires multiple strata of information, particularly relevant in several areas, so those stakeholders who are or may be affected by a decision should have the opportunity to contribute, based on their competence and ability, to the relevant operations and processes of SAI.

Criteria of procedural justice. Before analysing procedural justice, a specification is necessary. The normative goal of this political property may seem very similar to that of *input legitimacy* referred to above, since both relate to involvement in decisional processes. But with regard to SAI, the focus of input legitimacy would not be particularly relevant for this institution to work in the public interest. This is because input legitimacy focuses on an institution’s arrangements allowing stakeholders to communicate their interests to the institution’s decision-makers and therefore largely concerns external issues. Procedural justice, on the other hand, is relevant because it is pertinent to internal issues regarding the normative qualities of the institution’s decision-making: procedural justice covers a unique space of non-distributive normative problems, thereby differing from input legitimacy. This internal space relates to the agents who interact with an institution, whereas legitimacy concerns the arrangements through which an institution connects externally with stakeholders. Consequently, procedural justice imposes criteria and standards to SAI whose scope is different from the one legitimacy entails.

Procedural justice operates, however, in synergy with the notion of legitimacy employed to grant the openness, inclusiveness and independence necessary for SAI to work in the public interest. This section investigates procedural justice in order to develop criteria suitable for SAI.

Procedural justice deals with how relations between SAI and agents involved in it are managed and how the correct functioning of the *rules of the game* of such relations is safeguarded. The most important procedural rules of the game—to ensure openness, inclusiveness, and independence—refer to the participation and recognition of the involved agents (Barry, 2002), specifically to their fair involvement in SAI and to their understanding of the issues at stake.

The current analysis of procedural justice, echoing the earlier investigation of legitimacy, aims to understand which components of procedural justice SAI should include in order to maximise its ability to work in the public interest. This section, therefore, defines the most suitable criteria and the next section, based on these criteria, will outline the indications and governance options that the related standards can provide.

Drawing on Barry (2002, pp. 97–99), SAI procedural justice can be grounded in two fundamental criteria:

- *impartiality*: the involvement in SAI of agents, all of whom having parity of participation (Fraser, 2005);
- *equality of opportunity*: all agents must have the same opportunity to fully understand the issues at stake in SAI (Page, 2012).

The impartiality criterion means that SAI should ensure the involvement of agents on an equal footing: SAI can attain procedural justice when the same rules, procedures, and formalities are applied to all agents. In particular, SAI should incorporate agreed arrangements for how agents are selected for inclusion, for how they interact with each other on internal issues

and for how they connect with non-internal issues. The rules for agents should be non-arbitrary and non-biased. It is also necessary for the involved agents to control the functioning of such arrangements. Additionally, all SAI initiatives should maximise the cultural and social diversity of agents involved.

The equality of opportunity criterion relates in different ways to knowledge and is fundamental to reducing the complexity of SAI—one of its salient traits. Equality of opportunity means that all the involved agents’ concerns must be considered, such that potential conflicts are minimised between the institution itself and agents, and amongst agents, and that interactions between agents are seen as fair. Equality of opportunity is achieved when all agents play a proportionately equal role in SAI.

Standards of legitimacy and procedural justice in SAI

The current section outlines the implications for SAI of the standards of legitimacy and procedural justice, puts forward some consequent legitimate and procedurally just governance options for SAI to work in the public interest, and presents related examples of existing governance structures in other contexts.

Standards should be understood as *ordinal principles* that are designed to work synergistically, i.e., the better SAI satisfies all of them at the same time, the more the public can be confident that SAI is operating in the public interest. Standards need both to capture the complexity of criteria and to be *epistemically accessible* (Buchanan, 2013, p. 193), that is comprehensible by the largest possible number of agents, stakeholders, and outside subjects. This is not an easy combination and striking a balance between these two contrasting requirements might seem to be an intractable challenge. As emphasised above, standards should be wholly and continuously contextualised—that is with specific reference to the particular SAI enterprise—and the nature of the structure required is indicated in the next section.

Table 1 gives an overview of the criteria and standards of legitimacy in SAI. It is worth recalling that although their *labels* might be familiar, the originality of the proposed criteria and standards lies in their contents, scope, objectives, as specified above.

Standards of legitimacy

Avoidance of serious injustice context: Priority standard. The criterion of legitimacy *avoidance of serious injustice* compels SAI to prioritise the needs of the more vulnerable. Accordingly, the related standard of *priority (to the more vulnerable)* should abide by a moral principle that prevents SAI from imposing burdens on the more vulnerable that are greater than those suffered by the less vulnerable, and by no means should they exceed those already inflicted by the climate crisis. Additionally, the priority standard requires that SAI provides these vulnerable people with greater benefits than those enjoyed by those less vulnerable, now or in a future global heating scenario. This standard is in line with core moral requirements for more just social arrangements since it shifts the onus from those who bear a greater burden than fairness would require of them—i.e., the more vulnerable ones—

Table 1 Criteria and standards of legitimacy and procedural justice.

	Criterion	Standard
Legitimacy	Avoidance of serious injustice	Priority
	Provision of reliable information	Transparency
Procedural Justice	Impartiality	Involvement
	Equality of opportunity	Knowledge

Source: Author.

to those who shoulder lighter burdens, that is to say, wealthier agents.

In terms of governance, to avoid serious injustice the priority standard demands that SAI, as an institution, take into account the social vulnerability of the populations of the different climate subregions in order to increase more the well-being of the more vulnerable among them. This ‘ranking’ can be obtained through an index of social vulnerability to climate change (e.g., Grasso et al., 2014). Accordingly, SAI should be developed so as the benefits that the control of the solar radiation that it affords (e.g., less heat, more precipitations, etc.) accrue to the more vulnerable populations according to their calculated level of social vulnerability: the higher their social vulnerability, the higher proportionally their share of benefits to tackle their needs, priorities, and opportunities more effectively.

The proposed social vulnerability-based approach is consistent with a principle common to many governance structures, that of progressivity, which aims to distribute burdens and advantages fairly by attributing the bulk of an onus to those who can better shoulder it and by ensuring more support to those who are in more need. For instance, the governance of most fiscal systems around the world includes a progressivity principle to favour weaker segments of society through greater access to services and benefits, while demanding proportionally more contribution to wealthier ones.

Provision of reliable information context: Transparency standard. For SAI to achieve the overall trustworthiness required by the legitimacy criterion *provision of reliable information*, it must be sufficiently transparent in its dealings that stakeholders can monitor its functioning in the public interest effectively. Transparency would also allow SAI to promote accountability (Hale, 2008). To this end, three aspects of transparency are important. First, accurate information must be made available (regularly, not merely upon direct request) to all stakeholders at a reasonable cost; second, information must be accessible to all stakeholders (i.e., in readily usable forms) so that they can act on it; third, stakeholders who use this information should be able to hold the institution accountable (Buchanan and Keohane, 2006, p. 427). Therefore, the minimum required is that SAI should provide the appropriate types and amounts of information to all stakeholders on its goals, procedures, and performance. Additionally, this information should be conveyed to stakeholders in ways that make it possible for them to criticise and propose changes to said goals, procedures, and performance.

To achieve transparency SAI should include an ‘independent consultive forum’ (for details on its structure, overall goals, and novelty in the context of solar geoengineering, see the section “Continuous operationalisation of standards”) to monitor if its functioning is continuously aimed at the public interest. In particular, this forum should provide stakeholders and the general public with accessible information—continuously updated—to check whether the goals, procedures, and processes of the SAI enterprise at stake aim the public interest; additionally, the forum should allow stakeholders and the general public to propose modifications to such goals, procedures, and processes, if they lose their focus on the provision of collective benefits.

In the same spirit, Frontex, the European Union Border and Coast Guard Agency, involves a consultative forum. This governance structure is composed of key European and global institutions, international and civil society organisations, and other stakeholders to which Frontex must grant timely and effective access to information related to its functioning. Hence the consultative forum can check the agency’s respect of fundamental rights, its code of conduct, the operating of the complaints mechanism, and other right matters, and propose recalibrations of Frontex conduct in case of inconsistencies.

Standards of procedural justice

Impartiality context: Involvement standard. On procedural justice, the *impartiality* criterion demands that SAI involves all agents mentioned in section “Background issues and the criteria of legitimacy and procedural justice in SAI”. The *involvement* standard demands that the procedural justice in terms of involvement of this institution is monitored and controlled. To satisfy this standard, SAI should promote unbiased decision-making, ensure the consistency of its norms, procedures, processes, structures, and instruments across involved agents and over time and build in the mechanisms needed to ensure that all decisions are modifiable and reversible. This standard should also safeguard the fundamental moral, cultural and social values of agents (Grasso and Sacchi, 2015). In brief, to comply with the involvement standard, SAI should be proactive in favouring involvement: this requires that any SAI enterprise establishes a platform (possibly even virtual) to involve impartially agents. Accordingly, this platform should grant them the possibility (i) to check if decision-making is consistent across agents and is stable over time, at least in the short term; (ii) to revise the points that have made SAI’s decisional processes unfair; and (iii) to ensure that they are compatible with the fundamental moral and cultural values of the agents involved.

While in our knowledge there are no explicit examples of governance structures that established specifically such platform, the Council of Europe (CoE)—an international organisation founded in 1949 to uphold human rights, democracy, and the rule of law in Europe—includes procedural mechanisms that make it possible for agents involved to check and revise its decision-making processes and ensure the consistency with their moral and cultural values; these mechanisms also provide agents with accurate and validate knowledge about this organisation as required by the knowledge standard outlined below. Additionally, the CoE, in view of increasing involvement in decisional processes and facilitating them, was advised to create an online platform for e-participation which would also have the mandate to provide agents with further knowledge (ECNL, 2016).

Equality of opportunity context: Knowledge standard. The *equality of opportunity* criterion requires that the agents involved in an institution be equal—or close to equal—in terms of the opportunities they have to understand the functioning of such institution. To achieve this condition, SAI should provide access to accurate and authenticated knowledge, and/or develop its own, despite the inevitable current uncertainties. Given accurate knowledge, decision-making can be based on evidence rather than guesswork or personal bias, and it can thus maximise the benefit to be gained from the knowledge and competence of agents (Dolan et al., 2007). The *knowledge* standard aims to promote the active participation of agents in all SAI decisional processes through the generation, integration, and provision of timely and fit-for-purpose knowledge which reduces its complexity, even in the situation of profound unpredictability that this institution operates in.

The same platform outlined in relation to the involvement standard should make available to agents involved in a specific SAI enterprise accurate and validated (i.e., robust) knowledge about its functioning, in spite of the only certain trait of this institution, i.e., uncertainty. In fact, dealing with uncertainty requires multiple kinds of knowledge. In the context of SAI, this is particularly relevant in a number of areas. Agents must select and use sources of reliable and robust knowledge that constitute the basis for understanding the overall functioning of a complex institution such as SAI. Consequently, those agents should have an opportunity to contribute, based on their competence and ability, to the various aspects of the SAI enterprise at stake. They

should also have the necessary flexibility to rethink, reframe, and reshape them along these lines as new evidence and moral perspectives emerge.

In sum, to increase knowledge about its functioning, SAI, through the proposed platform, should have the capacity of generating, integrating, and providing involved agents with the timely and fit-for-purpose robust knowledge needed for overcoming uncertainties about its functioning even in a situation of deep unpredictability, as the CoE example outlined above shows.

Specifications and recommendations

The criteria and standards of legitimacy and procedural justice developed are not, however, definitive: horizontally, they may be more, or less, effective in some SAI initiatives than in others and longitudinally they may struggle over time to keep pace with the evolving contexts in which they operate. Additionally, standards provide only general indications: their operational details depend on the individual SAI enterprise and its ever-changing context, and they need to be continuously defined and redefined in socially agreed ways.

These considerations prompt two critical recommendations to increase the likelihood of SAI working in the public interest over time. First, legitimacy and procedural justice within SAI must be continuously checked and recalibrated; second, appropriate ways of continuously contextualising and operationalising standards should be established.

Check and calibration. Because SAI is as yet largely untried and untested, the inclusion of legitimacy and procedural justice requires some innovative thinking and original design work. Ingenuity, however—although often effective in uncertain situations—risks delivering solutions that are not uniformly applicable to all SAI enterprises, failing to keep up with evolving circumstances and losing the focus on the public interest.

The criteria and standards outlined above might then not always increase the overall legitimacy and procedural justice of SAI or be able to work beyond the short term. Therefore, a checking process will be vital, one which relies on the knowledge-generating potential of the criteria and standards themselves. The application of the reliable information criterion and the transparency standard, and the equality of opportunity criterion and the knowledge standard and of the related governance options, will enable SAI to carry out the most thorough possible critical review of its legitimacy and procedural justice and of its continuous ability to aim at the public interest.

But contexts change—SAI operates in a dramatically fast-evolving climatic, scientific, technological, economic, and socio-political landscape—and so, potentially, the criteria and standards of legitimacy and procedural justice could become inadequate. To obviate this risk, they should undergo a dynamic process of iterative learning, supporting an integrated-learning mode of adaptive governance. SAI should, by highlighting and appraising the degree of its consistency with the provisions of legitimacy and procedural justice, be able to calibrate and rearrange standards and criteria to uphold these two ideals over time. SAI's legitimacy and procedural justice should then be addressed in a social-learning mode, dynamically and reflectively (Grasso and Tàbara, 2019). This iterative process would also make SAI more consistent with the requirements of a *responsible research and innovation* approach. Its institutional complex would be able to engage and re-engage in multiple ways over long periods of time with agents, stakeholders and civil society in order to align its conduct and outcomes with their values and objectives (Low and Buck, 2020) and hence to truly work in the public interest.

Continuous operationalisation of standards. In order to ensure that the details of standards of legitimacy and procedural justice and of the governance options they indicate can be socially agreed upon for the specific SAI enterprise and modified when the contextual changes require it, the same independent consultative forum mentioned in the section “Standards of legitimacy” to achieve transparency will be beneficial. This governance structure would make the necessary decisions—taking into account the outcomes of the checking and calibration process described above—about the contextualised operationalisation and modification of standards. The forum is not a new suggestion in the relevant literature: various authors have proposed such decision-making governance structure (e.g., Chhetri et al., 2018; Nicholson et al., 2018; Reynolds, 2019). It is worth stressing here, however, that two distinctive features are needed if the forum is to have the independence necessary to shape, and maintain over time, the required standards of legitimacy and procedural justice.

First, the forum should be external to any SAI initiative, i.e., its members should have no stake in it. Only thus would the forum be both effective and credible and avoid accusations that SAI does not work in the public interest. Second, the make-up of the SAI consultative forum should be inclusive and diverse. It should involve three groups of members—experts, practitioners, and representatives from civil society—with a balance of gender and global South and the North and particular attention to the representation of more vulnerable parties. Experts should have scientific and/or technological knowledge about SAI and be selected internationally from both the physical and the social sciences communities working on SAI and its governance. The complexity of SAI makes it unfeasible to involve lay people effectively; therefore, the second group should consist of practitioners from NGOs working on climate engineering, including those concerned with the most-hard hit developing world. Examples would be the Solar Radiation Management Governance Initiative (SRMGI), the Carnegie Climate Governance Initiative (C2G), The World Academy of Sciences and the Environmental Defense Fund. The third group should include those parts of the global civil society which, despite not being involved in the SAI enterprise, are concerned by it as a wide-ranging socio-political and economic phenomenon: political representatives, social movements, networks of knowledge-based experts, and economic and financial circles.

Conclusions

This article puts forward a way to provide SAI with the long-term legitimacy and procedural justice it needs if it is to increase its capacity to operate in the public interest. To this end, the article first develops suitable criteria of legitimacy and procedural justice; it then goes on to investigate the indications and morally sound governance options provided by the related standards—epistemically accessible proxies of criteria; finally, it outlines two recommendations that will help ensure the achievement and maintenance of the legitimate and procedurally just functioning of SAI in the public interest.

It seems finally worth underlining that the establishment of legitimate and procedurally just SAI would both make it more effective as an institution and able to work in the public interest than could be achieved by any form of imposition, however great our trust in the vision of politicians, or in the exemplary power of scientific evidence. In the current fragmented and multipolar international climate order, all climate action needs to operate in a polycentric, quasi-anarchic system, through careful, gradual design and re-design of the relevant institutions. This especially applies to SAI, as it significantly interferes with vested interests, influences patterns of well-being across states, peoples, and generations, and

modifies the flow of huge amounts of resources, not least financial ones. The inclusion and maintenance of legitimacy and procedural justice in SAI would shape converging preferences among agents, stakeholders, and political representatives in support of this institution, even those coming from differing political traditions and subject to different political constraints. Ultimately, therefore, the likelihood that SAI would work in the best interests of the public would be significantly enhanced.

Received: 29 November 2021; Accepted: 24 May 2022;
Published online: 01 June 2022

References

- Adams NP (2020) Legitimacy and institutional purposes. *Crit Rev Int Soc Political Philos* 23:292–310
- Baatz C, Heyward C, Stelzer H (2016) The ethics of engineering the climate. *Environ Value* 25:1–5
- Barry B (2002) Political argument: a reissue with a new introduction. University of California Press, Berkeley, CA
- Bernstein S (2011) Legitimacy in intergovernmental and non-state global governance. *Rev Int Political Econ* 18:17–51
- Bodansky D (2013) The who, what, and whereof of geoengineering governance. *Clim Change* 121:539–551
- Bodle R et al. (2014) Options and proposals for the International Governance of Geoengineering. Ecologic Institute, Berlin. <https://www.ecologic.eu/11052>. Accessed 24 May 2022
- Bova S et al. (2021) Seasonal origin of the thermal maxima at the Holocene and the last interglacial. *Nature* 589:548–553
- Bradshaw CJ et al. (2021) Underestimating the challenges of avoiding a ghastly future. *Front Conserv Sci* 1:615419
- Brent K (2021) Solar geoengineering is prohibited under international law. In: Mayer B, Zahar A (eds) *Debating climate law*. Cambridge University Press, Cambridge, pp. 274–284
- Buchanan A (2010) The legitimacy of international law. In: Besson S, Tasioulas J (eds) *The philosophy of international law*. Oxford University Press, Oxford, pp. 79–96
- Buchanan A (2013) *The heart of human rights*. Oxford University Press, Oxford
- Buchanan A, Keohane RO (2006) The legitimacy of global governance institutions. *Eth Int Aff* 20:405–437
- Buck HJ et al. (2020) Evaluating the efficacy and equity of environmental stopgap measures. *Nat Sustain* 3:499–504
- Caldeira K, Govindasamy B, Cao L (2013) The science of geoengineering. *Annu Rev Earth Planet Sci* 41:231–256
- Callies DE (2018) Institutional legitimacy and geoengineering governance. *Eth Policy Environ* 21:324–340
- Callies DE (2019a) Climate engineering: a normative perspective. Lexington Books, Lanham, MD
- Callies DE (2019b) The slippery slope argument against geoengineering research. *J Appl Philos* 36:675–687
- Chhetri N et al. (2018). Governing solar radiation management. Forum for Climate Engineering Assessment, American University, Washington, DC. <https://doi.org/10.17606/M6SM17>. Accessed 24 May 2022
- Clark I (2005) *Legitimacy in international society*. Oxford University Press, New York
- Dolan P, Edlin R, Tsuchiya A, Wailoo A (2007) It ain't what you do, it's the way that you do it: characteristics of procedural justice and their importance in social decision-making. *J Econ Behav Organ* 64:157–170
- Dove Z, Horton J, Ricke K (2021) The middle powers roar: exploring a unilateral solar geoengineering deployment scenario. *Futures* 132:102816
- Downs A (1962) The public interest: Its meaning in a democracy. *Soc Res* 29:1–36
- ECNL—European Center for Not-for-profit Law (2016) Civil participation in decision-making processes. An overview of standards and practices in Council of Europe member states. ECNL, Strasbourg. <https://rm.coe.int/civil-participation-in-decision-making-processes-an-overview-of-standards/1680701801>. Accessed 24 May 2022
- Fischer EM, Sippel S, Knutti R (2021) Increasing probability of record-shattering climate extremes. *Nat Clim Chang* 11:689–695
- Fraser N (2005) Reframing justice in a globalizing world. *New Left Rev* 36:69–88
- Frumhoff PC, Stephens JC (2018) Towards legitimacy of the solar geoengineering research enterprise. *Philos Trans R Soc A* 376:20160459
- Grasso M, Moneo M, Arena M (2014) Assessing social vulnerability to climate change in Samoa. *Reg Environ Change* 14:1329–1341
- Grasso M, Sacchi S (2015) Impure procedural justice in climate governance systems. *Environ Value* 24:777–798
- Grasso M (2019) Sulfur in the sky with diamonds: an inquiry into the feasibility of solar geoengineering. *Glob Policy* 10:217–226
- Grasso M, Tabara JD (2019) Towards a moral compass to guide sustainability transformations in a High-End Climate Change world. *Sustainability* 11:2971
- Grasso M (2022) *From big oil to big green. Holding the oil industry to account for the climate crisis*. MIT Press, Cambridge, MA and London
- Hale TN (2008) Transparency, accountability and global governance. *Glob Gov* 14:73–94
- Halstead J (2018) Stratospheric aerosol injection research and existential risk. *Futures* 102:63–77
- Hamilton C (2013) No, we should not just ‘at least do the research’. *Nature* 436:139
- Horton JB, Reynolds JL (2016) The International politics of climate engineering: a review and prospectus for international relations. *Int Stud Rev* 18:438–461
- Horton JB et al. (2018) Solar geoengineering and democracy. *Global Environ Politics* 18:5–24
- Hurrell A (2005) Legitimacy and the use of force: can the circle be squared? *Rev Int Stud* 31:15–32
- IPCC—International Panel on Climate Change (2022) AR6 climate change 2022: impacts, adaptation, and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge
- Jinnah S, Nicholson S, Flegel J (2018) Toward legitimate governance of solar geoengineering research: a role for sub-state actors. *Eth Policy Environ* 21:362–381
- Jinnah S et al. (2019) Governing climate engineering: a proposal for immediate governance of solar radiation management. *Sustainability* 11:3954
- Kaufman D et al. (2020) A global database of Holocene paleotemperature records. *Sci Data* 7:115
- Keith DW (2013) *A case for climate engineering*. MIT Press, Cambridge
- Kelly PM, Adger WN (2000) Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Clim Change* 47:325–352
- Keohane RO (2011) Global governance and legitimacy. *Rev Int Political Econ* 18:99–109
- Lenton TM et al. (2019) Climate tipping points—too risky to bet against. *Nature* 575:592–595
- Low S, Buck HJ (2020) The practice of responsible research and innovation in “climate engineering”. *WIREs Clim Change* 11:e644
- MacMartin DG, Ricke K, Keith DW (2018) Solar geoengineering as part of an overall strategy for meeting the 1.5 C Paris target. *Philos Trans R Soc A* 376. <https://doi.org/10.1098/rsta.2016.0454>
- Masson-Delmotte V (2021) Climate change 2021: the physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge
- McLaren D (2016) Mitigation deterrence and the “moral hazard” of solar radiation management. *Earth's Future* 4:596–602
- McLaren D, Corry O (2021) The politics and governance of research into solar geoengineering. *Witres Clim Change* 12:e707
- Moriyama R et al. (2017) The cost of stratospheric climate engineering revisited. *Mitig Adapt Strateg Global Change* 22:1207–1228
- Morrow DR (2020) A mission-driven research program on solar geoengineering could promote justice and legitimacy. *Crit Rev Int Soc Political Philos* 23:618–640
- Morrow DR, Kopp RE, Oppenheimer M (2013) Political legitimacy in decisions about experiments in solar radiation management. In: Burns WCG, Strauss AL (eds) *Climate change geoengineering: philosophical perspectives, legal issues, and governance frameworks*. Cambridge University Press, Cambridge, pp. 146–167
- Nicholson S, Jinnah S, Gillespie A (2018) Solar radiation management: a proposal for immediate polycentric governance. *Clim Policy* 18:322–334
- Page EA (2012) The hidden costs of carbon commodification: emissions trading, political legitimacy and procedural justice. *Democratization* 19:932–950
- Parson EA (2017). Starting the dialogue on climate engineering governance: a World Commission. Policy Brief: Fixing Climate Governance Series, Waterloo, Ontario. <https://www.cigionline.org/publications/starting-dialogue-climate-engineering-governance-world-commission>. Accessed 24 May 2022
- Pasztor J et al (2019) Geoengineering: the need for governance. C2G, New York. <https://www.c2g2.net/the-need-for-governance/>. Accessed 24 May 2022
- Pasztor J, Scharf C, Schmidt K-U (2017) How to govern geoengineering? *Science* 357:231
- Pettit P (2012) Legitimacy and justice in republican perspective. *Curr Legal Probl* 65:59–82
- Philip SY et al (2021) Rapid attribution analysis of the extraordinary heatwave on the Pacific Coast of the US and Canada June 2021. *Earth Syst Dynam*. Preprint at <https://doi.org/10.5194/esd-2021-90>

- Pierrehumbert RT (2017) The trouble with geoengineers “hacking the planet”. *Bull Atom Sci Anal.* <https://thebulletin.org/trouble-geoengineers-%E2%80%9C9Chacking-planet%E2%80%9D10858>. Accessed 24 May 2022
- Rawls J (2005) *Political liberalism: expanded edition*. Columbia University Press, New York
- Reynolds JL (2019) Solar geoengineering to reduce climate change: a review of governance proposals. *Proc R Soc A* 475:20190255
- Reynolds JL (2022) Linking solar geoengineering and emissions reductions: strategically resolving an international climate change policy dilemma. *Clim Policy* 22:285–300
- Sabel CF, Victor DG (2017) Governing global problems under uncertainty: making bottom-up climate policy work. *Clim Change* 144:15–27
- Schäfer S et al (2015) The European transdisciplinary assessment of climate engineering (EuTRACE): removing greenhouse gases from the atmosphere and reflecting sunlight away from Earth. <https://www.adelphi.de/en/publication/european-transdisciplinary-assessment-climate-engineering-eutrace>. Accessed 24 May 2022
- Scharpf FW (1970) *Demokratietheorie zwischen utopie und anpassung*. Universitätsverlag, Konstanz
- Scharpf FW (1999) *Governing in Europe. Effective and democratic?* Oxford University Press, Oxford
- Shue H (2015) Historical responsibility, harm prohibition, and preservation requirement: core practical convergence on climate change. *Moral Philos Politics* 2:7–31
- Solar Radiation Management Governance Initiative (SRMGI) (2011) *Solar radiation management: the governance of research*. <https://royalsociety.org/topics-policy/projects/solar-radiation-governance/report/>. Accessed 24 May 2022
- Steffek J (2015) The output legitimacy of international organizations and the global public interest. *Int Theor* 7:263–293
- Suarez P, van Aalst MK (2017) Geoengineering: a humanitarian concern. *Earth’s Future* 5:183–195
- Svoboda T (2017) *The ethics of climate engineering: solar radiation management and non-ideal justice*. Routledge, New York
- Szerszynski BKM et al. (2013) Why solar radiation management geoengineering and democracy won’t mix. *Environ Plan A* 45:2809–2816
- Talberg A, Christoff P, Thomas S, Karoly D (2018) Geoengineering governance-by-default: an earth system governance perspective. *Int Environ Agreem* 18:229–253
- Tsipiras K, Grant WJ (2022) What do we mean when we talk about the moral hazard of geoengineering? *Environ Law Rev* 24:27–44
- Winsberg E (2021) A modest defense of geoengineering research: a case study in the cost of learning. *Philos Technol* 34:1109–1134
- Xu C, Kohler TA, Lenton TM, Svenning J-C, Scheffer M (2020) Future of the human climate niche. *PNAS* 117:11350–11355
- Zhang Y, Held I, Fueglistaler S (2021) Projections of tropical heat stress constrained by atmospheric dynamics. *Nat Geosci* 14:133–137
- Zürn M, Schäfer S (2013) The paradox of climate engineering. *Glob Policy* 4:266–277

Zürn M, Stephen M (2010) The view of old and new powers on the legitimacy of international institutions. *Politics* 30:91–101

Acknowledgements

The author thanks the PIASt—Polish Institute of Advanced Studies of the Polish Academy of Sciences (PAN—Polska Akademia Nauk) for having provided the means and the much-appreciated peace and quiet to think and work on this article.

Competing interests

The author declares no competing interests.

Ethical approval

Not applicable.

Informed consent

Not applicable.

Additional information

Correspondence and requests for materials should be addressed to Marco Grasso.

Reprints and permission information is available at <http://www.nature.com/reprints>

Publisher’s note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit <http://creativecommons.org/licenses/by/4.0/>.

© The Author(s) 2022