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Normative Uncertainty in Solar Climate Engineering Research Governance

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ABSTRACT

This paper explores what kind of uncertainty a research program governing solar climate engineering through Stratospheric Aerosol Injection (SAI) needs to account for. Specifically, it tries to answer two central issues with regards to SAI research and its ethical evaluation: One, what irreducible uncertainties remain throughout the decision-process, and, two, how do these remaining uncertainties affect the ethical evaluation of SAI research. The main assumption is that decisions on SAI research governance will be made under normative uncertainty, i.e. situations under irreducible knowledge-constraints that arise in concrete, practical decision-contexts. These decision-contexts are multi-lateral and empirically ambiguous, and the decision-makers need to reconcile a plurality of values. While normative uncertainty complicates the ethical evaluation of policy decisions, I argue that moral considerations can be accommodated through the inclusion of recognitional, participatory justice approaches, as well as adaptive and anticipatory governance methods.

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Normative uncertainty; solar climate engineering; participatory justice; adaptive planning; anticipatory governance

I. Introduction

Given the dire outlook and urgency of climate change, technological solutions are being discussed by researchers and policy makers alongside proposals for adaption and radical mitigation. A particularly impactful, potential climate technology is the concept of climate engineering, i.e. intentionally manipulating the climate system through technological means (Keith, 2001; Shepherd et al., 2009)

One way of conducting climate engineering could be through so called Stratospheric Aerosol Injection (henceforth SAI). SAI would artificially slow down the warming of the planet by increasing the stratosphere's reflection levels. Increasing the planet's albedo through SAI entails spraying aerosol particles into the stratosphere, which in turn reduces some of the incoming sunlight (Crutzen, 2006). However, the ethics surrounding SAI are contentious and polarizing raising issues of distributive, participatory and historical (in) justice, the relationship between human beings and nature, risk-ethical issues, etc. (Pamplany et al., 2020)

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Although SAI receives marginal but continuous attention within the ethics literature (for an overview, e.g. Preston, 2013), a focus on the uncertainties in the debate is still lacking. Specifically the implications and limitations uncertainty causes for the ethical assessment of SAI are in need of investigation.

While the very intention of SAI is to have a global effect, i.e. reducing the rate of warming, many of its effects, such as regional impacts, as well as its societal consequences are shrouded in considerable, at times irreducible uncertainty. Irreducible in this case entails that the uncertainty cannot be resolved through more empirical research or ethical analysis. Rather, the decision-process needs to take place under uncertainty. Such irreducible uncertainty in SAI research poses a challenge for its ethical assessment, which opens up two central questions. Namely, what kinds of irreducible uncertainties remain, and, how can these remaining uncertainties be ethically accounted for in the decision-making process?

In order to answer these two questions, I propose an adapted notion of normative uncertainty, that builds on previous notions of uncertainty as discussed within the scholarship surrounding precaution, decision theory and metaethics, as well as Responsible Research and Innovation. I argue that normative uncertainties are epistemic states wherein decision-makers have no unequivocal answer to a given question due to both the empirical circumstances of the situation as well as its ethical context. They arise in multi-lateral decision-situations that are empirically ambiguous, and wherein the decision-makers need to reconcile a plurality of different values. Normative uncertainties are not mere value disagreements, but rather challenge the adequacy and applicability of any given value due to the empirically uncertain circumstances (e.g. a lack of predictability and understanding of the empirical facts surrounding a given decision).

Importantly, the notion of uncertainty presented here is contextualized within the complexity of climate policy-making. This entails embedding decision-making under uncertainty within a multi-agential decision-space, representing numerous and diverse stakeholders, which in turn adhere to diverse ethical convictions. Decisions surrounding SAI, an inherently global intervention, can only be made sense of within this context of complex, multi-agential and global consideration.

[Section I](#) contextualizes the piece within the state-of-the-art SAI research governance literature, specifically focusing on the National Academies' 2021 report on solar climate engineering research governance. On this basis, [Section II](#) lays out how SAI research relates to the concept of precaution and uncertainty, arguing that precaution merely focuses on the empirical aspect of uncertainty. This focus on empirical uncertainty ignores the way in which moral disagreement and value pluralism lead to moral uncertainty. Consequently, the third section discusses ways of implementing moral uncertainty, found in decision theory and metaethics, into the broader, concept of normative uncertainty, accounting for both moral and empirical uncertainty. [Section IV](#) offers a working definition of normative uncertainty, while [Sections V, VI and VII](#) present procedural justice and anticipatory governance approaches as means to account for this uncertainty. The concluding section offers some underlying worries of SAI research and climate change.

II. Solar Climate Engineering and Research Governance

Solar climate engineering¹ entails reducing incoming sunlight by increasing the earth's reflection level. One potentially highly effective way of doing this is by releasing aerosols into the stratosphere, an approach referred to as Stratospheric Aerosol Injection (SAI). On the basis of modeling,² SAI is assumed to increase the reflection of incoming sunlight, which in turn leads to slowing down the warming of the planet, hence the oft-used umbrella term 'Solar Radiation Management' or 'Modification'³ (Crutzen, 2006; Niemeier & Tilmes, 2017; Robock et al., 2009; Shepherd et al., 2009).⁴

However, the prospect of intentionally manipulating the climate is highly contentious, and passionately debated throughout the climate ethics literature. Opponents of researching the approach highlight how SAI may perpetuate unjust power structures, and represents the pinnacle of human hubris (Hamilton, 2014; Schneider, 2019). Others criticize how it is a form of 'moral hazard', wherein the possibility of climate engineering might distract from mitigation efforts (Gardiner, 2009), or how its narrow focus on merely one aspect of the earth system is untenable as a solution to the complex challenge of climate change (Hulme, 2014). A main point of criticism that combines all the above, is that SAI carries incredible risks and uncertainties for the planet and its inhabitants, and is an immoral continuation of existing climate injustices.

To this central concern, proponents of research usually point out that the models so far show a decisive number of benefits of deployment over non-deployment in terms of risks, when compared to the current climate change trajectory (Crutzen, 2006; Keith, 2013; Keith and Irvine, 2016; Moreno-Cruz & Keith, 2013). Further, scholars highlight the necessity to engage in SAI research on prudential reasons. Due to its high impact on the climate and comparably low costs, climate economist Gernot Wagner for example touts the decision surrounding SAI as a situation of 'not *if*, but *when*' (Wagner, 2021). Importantly, SAI is not proposed by most of its proponents as an alternative to mitigation, but rather as a potential part of a diverse climate action portfolio, alongside thorough mitigation and adaptation.

Moving beyond the controversy of whether research should be conducted in the first place, some scholars have proposed research governance frameworks. These seek to explore how an institutionalized SAI research program could be governed by, among other things, ethical considerations and principles (Gardiner & Fragnière, 2018; Rayner et al., 2013; Stilgoe et al., 2013; Tuana et al., 2012).

Mainly, these frameworks focus on how ethical considerations should play a central role throughout the research process⁵ of SAI, emphasizing that '[...] ethical analysis be coupled with scientific analysis, and that funding agencies recognize the importance of such work through establishing funding programs for coupled ethical-scientific analyses of SRM'. (Tuana et al., 2012, p. 143). These integrated research governance frameworks seek to go beyond mere ethical analysis, but try to combine the science with the ethical, and socio-political issues at hand (e.g. supporting the political decision of research funding schemes and institutions).

An important aspect of these frameworks is the assessment of uncertainties arising throughout the research and potential deployment process. The science of SAI itself is riddled with uncertainties (Kravitz & MacMartin, 2020). A comprehensive piece of

scholarship on the intersection between governance and policy-making, the 2021 report on researching solar climate engineering from the National Academies of Sciences and Medicine (*NASEM*), states that

A principal goal of any research program should be to better characterize and reduce scientific and societal uncertainties concerning the benefits and risks of SG [SAI] deployment (relative to global warming in the absence of SG [SAI]). (2021, p. 6)

It seems fairly obvious that any research effort should aim at reducing, or when possible even eliminating uncertainties related to the subject matter studied. However, there are important limitations to the degree of how much uncertainties can be reduced, as the report acknowledges.⁶

From an empirical perspective, the only way to deal with uncertainties is by engaging in more research, and learning as much as possible about SAI. This is no doubt necessary and should be a central role of any SAI research program. Yet, taking the potential irreducibility of some uncertainties seriously also highlights the fact that decisions surrounding SAI will have to be made under degrees of uncertainty.

The uncertainty of making decisions on SAI relates to both the societal and physical impacts of a potential research program. As the report claims, '[s]ome degree of uncertainty will be a persistent feature of SG technologies, especially at regional scales, as a direct result of uncertainties in the underlying climate model' (2021, p. 117). Further, the uncertainty does not only relate to empirically measurable facts. Uncertainty also arises with regards to the moral assessment of SAI research governance, for example how much (empirical) uncertainty is ethically acceptable when making decisions on SAI, or what kind of justice considerations should be given priority.

The following section analyses the decision-making space surrounding SAI research governance. Namely, decisions on SAI research governance arise in an ambiguous, multi-generational and multi-lateral decision-process that needs to reconcile diverse ethical considerations with incomplete empirical knowledge. These decisions take place under irreducible empirical as well as moral uncertainty, i.e. uncertainty that arises in value-pluralist contexts. This takes the current STS and ethics of technology literature as a vantage point, exploring how this scholarship has so far attempted to deal with the phenomenon of uncertainty. I use the example of different renditions of the precautionary principle, which I claim are suitable to account for empirical uncertainty, but need to be adapted in order to deal with uncertainty arising on the basis of incompatible values.

III. Empirical Uncertainty and the Limits of Precaution

A main reason why risk and uncertainty are ever-present when thinking about new and emerging technologies, is due to the lack of foresight and prediction. There is no objective, incontestable data that a group of decision-makers could refer to in order to settle disagreements, or find a 'best solution'. The data and information policy-makers need to rely on in such situations is ambiguous, i.e. the relevant empirical considerations to reach a decision can all be reasonably contested.

The empirical facts surrounding SAI, and climate science more generally, are contentious and rely heavily on specific interpretations of data sets through models, and the construction of scenarios. Increasingly complex models aim to incorporate socio-

economic developments, alongside climate responses (e.g. Integrated Assessment Models), and thereby become part of the decision-process. However, models are by definition not a complete representation of the real world, and while their inclusion is useful for making robust policy decisions, their inherent incompleteness and ambiguity gives rise to uncertainty for decision-makers.⁷

It should be noted that having to make decisions under risk and uncertainty in the policy realm surrounding technology and climate change is not a novelty. Philosophers and Science and Technology (STS) scholars alike have discussed the ethical and societal implications of modern technology, and the uncertainties they inevitably produce. Authors such as Ulrich Beck have argued that a central feature of modernity is its continuous production, imposition and resolution of risks imposed through and alleviated by technology (Beck, 1992). Similarly, Sheila Jasanoff points toward humility as a guiding principle when dealing with complex societal problems through technology and policy, in which '[u]ncertainty, indeterminacy, and ignorance are always present'. (Jasanoff, 2007, p. 33) The way new technologies shape society and the environment are particularly pertinent in terms of their unintended consequences, and raises the question how humility and a new form of responsibility can account for these issues.

With the mainstream realization that the negative environmental and human health issues produced by neoliberal economic growth and exploitation paradigms are out-pacing potential solutions, the so called 'Precautionary Principle' has gained prominence (Kriebel et al., 2001). The Precautionary Principle (PP) offers a way forward in situations of irreducible empirical uncertainties for environmentally impactful innovation and policy-decisions. Specifically, precaution highlights the importance of avoiding actions that could cause unacceptable harm, even in the absence of scientific proof that the action will cause said harm. In other words, when making a decision under empirical uncertainty, it is better to err on the side of caution.

There have been numerous attempts at synthesizing diverse accounts of the PP into a coherent, single definition (Gardiner, 2006; Steel, 2015). While certain core themes seem to form part of any PP, such as variations of Manson's *Activity – Effect – Remedy* tripod (Manson, 2002), I follow Lauren Hartzell-Nichols' argument that any PP needs to be appropriately contextualized and adapted to a given decision-situation (Hartzell-Nichols, 2017). In other words, there is not one Precautionary Principle, but rather a number of contextualized decision-making principles that highlight a contextualized form of precaution.

What all renditions of the PP do share, is that they seek to deal with uncertainties that are of scientific and empirical nature. These are uncertainties that arise in ambiguous situations wherein groups of decision-makers do not have access to the necessary information and therefore ought to better be 'safe than sorry'. Hartzell-Nichols, in her book on precaution and climate change, describes the uncertainties we face in climate policy poignantly:

We are now quite certain *that* climate change is happening, but uncertainty abounds in our understanding of exactly *what* will happen, given different emissions and policy scenarios. We know climate change will be bad, but we do not know exactly *how* bad it will be *when* and *for whom*. We are therefore in a position where we must decide what to do about the risks climate change threatens in the face of a range of uncertainties. (2017, p. 27, italics from original)

All the italicized terms in the quote are descriptive pointers: The uncertainty is a matter of lacking knowledge and understanding.⁸ This uncertainty that stems from a lack of knowledge is often referred to as ‘empirical’ uncertainty in decision-theoretical and policy literature (Walker et al., 2003). Marchau and colleagues for example describe making a decision under uncertainty as ‘the gap between available knowledge and the knowledge decision makers would need in order to make the best policy choice’. (Marchau et al., 2019, p. 2) On their account, there is an ‘uncertainty-gap’ that represents the missing knowledge necessary to make a prudent choice. This uncertainty-gap is to be filled with empirical information, such as observable facts and data, hence the moniker ‘empirical’.

Coming back to the PP, this empirical uncertainty is framed first and foremost as an obstacle for the decision-making process, as it blurs and contests available information. Examining the core dimensions of the PP, Per Sandin for example writes that ‘uncertainty [...] expresses our (lack of) knowledge of [...] possible states of the world’. (Sandin, 1999, p. 892) However, this focus on empirical uncertainty runs the risk of overshadowing the equally impactful ethical aspects that ambiguous, value pluralist and multi-lateral decision-contexts need to account for. Importantly, empirical uncertainty impedes the unequivocal application of any given set of values or norms. If the impact of an action is shrouded in empirical uncertainty, the contextualization of moral judgments becomes uncertain as well.

Thus, beyond empirical uncertainty, the uncertainty related to decision-making on SAI research governance is also grounded in the moral realm, raising the question what kinds of values, norms, and ethical considerations motivate reasons for and against research in the first place. In other words, besides empirical uncertainty, decisions surrounding SAI research governance also give rise to *moral uncertainty* due to the empirical ambiguity and its multi-agential and multi-lateral decision-space.

IV. Metaethical Moral Uncertainty and Practical Limitations

Originally, moral uncertainty is a term related to decision-theory and metaethics. However, I believe that there are two dimensions of moral uncertainty that need to be addressed for clarification, specifically to contextualize it within SAI research governance. The first dimension can be referred to as meta-theoretical uncertainty, which is the dimension scholars currently mostly focus on. Scholarship dealing with this dimension of moral uncertainty seeks to find heuristic tools in order to overcome the uncertainty a single agent finds herself in, when trying to know what moral theory or concept is ‘correct’. Scholars thus aim to answer the question how we should act if we do not know what the ‘correct’ moral theory is.

As an example, meta-theoretical uncertainty arises when one is uncertain about whether we should be vegetarians or not (MacAskill, 2016, p. 987).⁹ Importantly, this meta-theoretical approach toward moral uncertainty treats the issue as a problem to be overcome through rational decision-making (MacAskill, 2016; MacAskill et al., 2020; Sepielli, 2014). Accordingly, in a recent book, MacAskill et al. (2020) try to deal with moral uncertainty by outlining an array of decision-theoretical tools, relying on the ‘maximization of expected choiceworthiness’ when comparing different theories. The decision of choosing a moral theory is relegated to a meta-theoretical equation, that produces a numerical value upon which the ‘best’ theory for a decision can be assessed.

Although MacAskill et al's approach is based on complex theoretical structures, their goal is to answer a practical question: How should a decision-maker act if they do not know which moral theory is correct? Their focus is explicitly on dealing with the uncertainty of moral questions as they relate to our individual decisions and the underlying reasons for these decisions, those reasons being moral theories. Should I tell a white lie or not, is translated into: Should I be a Kantian or a utilitarian?¹⁰

The meta-theoretical dimension of moral uncertainty assumes that moral uncertainty stems from disagreement about the ethical theories that underlie moral decisions. It is important to note here that we can take moral uncertainty to be an issue regardless of our metaethical stance, if one agrees that uncertainty occurs when making moral deliberations.¹¹ As long as it can be agreed upon that one *can reason* about morality in some shape or form, moral uncertainty is a relevant phenomenon. A moral theory then does not necessarily entail any assumption of truth analogous to scientific truths, but it can answer questions such as what behavior and values are adequate, accepted, tolerated, etc.

While the meta-theoretical dimension of moral uncertainty is an important philosophical issue, it is not directly applicable to decision-making on SAI research governance. This is because the meta-theoretical dimension does not seek to account for the multi-lateral, value-pluralist and empirically ambiguous decision-context under which such decisions take place.

The uncertainty about the ethical aspects of a decision on SAI and research governance do not merely arise because decision-makers face theoretical struggles in coming to satisfying philosophical conclusions. Rather, moral uncertainty arises in its second dimension, which is the pragmatic necessity of making decisions based on contestable values, norms, or beliefs under empirically uncertain circumstances.¹²

SAI specifically produces moral uncertainty due to its global nature and uncertain impacts. It forces an international community to agree on the prioritization of a set of values that should govern the research of a technology with tangible global and inter-generational impacts, while those impacts are themselves uncertain. As with any decision that is being made in a value-pluralist context, some ethical considerations will take precedence over others. Some conceptions of justice, well-being, or autonomy will be given priority, especially given the fact that some ethical conceptions and their realization may be mutually exclusive.

This situation of multi-lateral value pluralism inevitably raises a specific kind of uncertainty among decision-makers, namely the practical issue of reconciling differentiating ethical positions that have no unequivocal reference point to settle the disagreement. We could of course claim that this is a similar situation to what philosophers and ethicists face when they try to account for meta-theoretical moral uncertainty. After all, MacAskill and colleagues' aim is to establish a method of reducing questions of moral uncertainty to an equation that solves for the highest 'expected choice-worthiness'.

However, this approach is not tenable when dealing with moral uncertainty in a global policy context. Policy-makers need to take into account not only coherent, philosophical reasoning, but (and arguably more importantly) the interests, claims, and rights of the constituents they represent. Whether and how to govern SAI research will ideally not be made by a single agent who finds herself struggling to combine a given ethical theory with ambiguous modeling results¹³. Rather, the decision-making process on SAI ought to

entail broad participation by a number of experts and shareholders, with a specific focus on recognizing those most vulnerable to large-scale experimentation. These may all bring a number of differing ethical considerations, such as conceptions of justice and precaution to the table, which in turn complicate the decision-process.

At the same time, the contextualization of these ethical considerations can only be made under tacit assumptions of the kind of impacts the technology *might* have. However, those tacit assumptions can be reasonably challenged throughout, which calls the initial value-judgment they were based on into question. Given the empirical ambiguity and socio-political reality of climate policy decision-making, the meta-theoretical concept of moral uncertainty needs to be adapted to include moral uncertainty in policy-decisions.

V. Normative Uncertainty in SAI Decision-Making: A Working Definition

Based on the previous analysis of empirical and moral uncertainty, and the limitations of these concepts within the policy-space, we have now established a baseline to answer the question what kinds of uncertainties remain throughout the decision-process on SAI research. I argue that the uncertainties that remain are what I refer to as Normative Uncertainties (NU). Normative uncertainties are irreducible knowledge-constraints that arise in concrete, practical decision-situations. These decision-situations are multi-lateral and empirically ambiguous, wherein the decision-makers need to reconcile a plurality of values.

NU cannot be reduced to purely empirical or moral considerations. Rather, NU highlights the relationship between empirical facts and moral evaluation as central to any holistic ethical governance framework. While the 'facts' are invaluable, they seldom exist in a moral vacuum and their interpretation needs to be combined with an active reflection of the values and norms at play in the decision. At the same time, the ethical evaluation needs to be connected to the best interpretation of the current state of the world available, if it is to be both justifiable and feasible.

It is important to note that the concept of normative uncertainties I present here is not entirely novel. Especially with regards to climate policy, the taxonomy of normative uncertainties outlined by Taebi et al. (2020) needs to be mentioned. The authors introduce their notion of normative uncertainty as '[a] situation, in which there are different partially morally defensible but incompatible options or courses of action, or in which there is no fully morally defensible option'. (2020, p. 2) According to Taebi and colleagues, these uncertainties can be categorized in relation to the different reasons why they arise. Namely, they propose four different kinds of normative uncertainty: Epistemic, evolutionary, theoretical, & conceptual.

Epistemic normative uncertainty arises when there is insufficient empirical knowledge about a climate adaption proposal, which in turn raises ethical questions of evaluating uncertain impacts, and how to morally assess the imposition of risks and uncertainties. Evolutionary normative uncertainty accounts for the possibility of future generations holding different values than the decision-making generation. Since policy-decisions, especially regarding long-term, intergenerational infrastructure projects, are inherently guided by certain values, the possibility of those values no longer holding in the future needs to be taken into account. Finally, theoretical and conceptual uncertainty arise when

different ethical conceptions or theories need to be reconciled throughout the decision-process. For example, the concept of ‘justice’ – what it consists of, how it could be achieved – is of central concern for debates surrounding political theory and philosophy that raises all kinds of conceptual and theoretical disagreements.

While the taxonomy of normative uncertainties makes up the majority of the article, Taebi et al. put forward a brief proposal for how such uncertainties could be dealt with on a decision-making level. Namely, they point toward a reflective decision-framework, inspired by John Rawls’ Wide Reflective Equilibrium, and the emerging literature on adaptive planning (2020, p. 7). The next section engages with these possible solutions in more detail. Before moving on, however, it is necessary to position my proposal of NU in relation to Taebi et al’s taxonomy.

There are a number of obvious overlaps between their approach and mine. Most importantly, I agree with the assumption that uncertainty is not merely the lack of measurable, empirical knowledge (what they refer to as *epistemic*), but also inextricably linked to moral considerations, such as value judgments and ethical background theories. Further, I concur with the notion that ‘uncertainty in decision-making is not necessarily an undesired state of affairs that we should get rid of’. (2020, p. 4) While I have similarly described normative uncertainty as a knowledge-constraint, this does not entail that its ethical potential is purely negative. Uncertainty can also make room for previously marginalized voices and unthought moral considerations and scenarios. Uncertainty in policy-making can make space for flexibility and learning (Stirling, 2010).

With SAI research, irreducible uncertainty underscores the fact that there is a limit to how much certainty policy-makers can hope for when making a decision. The concept of NU I present here, can help with the decision-making process to identify knowledge-constraints throughout the decision’s ethical evaluation. My focus on the procedural aspects of decision-making, as well as the decision-space in which it arises, contrasts it with Taebi, Kwakkel, and Kermisch’s work. In this sense, I see my approach as a supplementary piece that contextualizes normative uncertainties beyond the climate adaption realm, and brings them into the discussion on new and emerging (climate) technologies, specifically SAI research governance.

This assessment of normative uncertainties then answers the first question of what kinds of uncertainties remain when having to make decisions on SAI research. With this backdrop of in mind, we can now turn to the second part of the question: How can we ethically account for NU?

VI. Normative Uncertainty and Procedural Justice in Policy-Making

Given the empirically ambiguous, and value pluralist decision-context of SAI research, ethically reflected policy-makers are hard-pressed to find incontestable scenarios and undisputable moral values which could support their policy-decisions. Normative uncertainty challenges ultimate truths and unequivocal answers. However, if a clear assessment of what specific values should guide the decisions is impossible, we can turn to the procedure itself. In other words, instead of focusing on what kind of decision-outcomes are and are not justified, we can focus on the process of just decision-making itself.

In political philosophy, focusing on the just process of a decision is referred to as procedural justice. Procedural justice can be contrasted with the notion of substantive justice. Broadly and reductively speaking, the distinction between the two can be brought forth through their different answers to the question: What makes something just – its deliberative procedure, i.e. how the decision was reached, or the outcome of the decision? A purely proceduralist account of justice (Nozick, 1974)¹⁴ would answer that what can be deemed just ultimately depends on whether a decision is based on a just process. Substantive justice approaches instead focus on the outcome of the procedure, e.g. whether certain goods were distributed in a just way.¹⁵

In line with procedural thinking, I propose that one way to account for the ambiguous and value-pluralist decision-space of SAI research, is through a process of robust participation. The normative uncertainty that arises necessitates a procedural, rather than a substantive approach for a simple reason. What the precise substance of justice is, what kind of distribution of well-being and harm among different regions for example, should matter, is what decision-makers – if a legitimate plurality of values and empirical ambiguity is taken into account – are uncertain about in the first place. Making substantive claims about who should bear which burden would leapfrog the procedure of justifiably reaching those substantive claims, and assume that there are unambiguous empirical facts and predictions available to substantiate those claims.

Following Axel Honneth and Nancy Fraser's seminal work on participation and recognition, the decision-procedure I propose relies on the normative assumption that a just procedure requires the 'parity of participation', i.e. that 'social arrangements [. . .] permit all (adult) members of society to interact with one another as peers'. (Fraser & Honneth, 2003, p. 36)¹⁶ Translated into the realm of climate policy, where including the individual say of each and every affected member is virtually impossible, participatory parity can only be achieved through representation (Hourdequin, 2019, p. 35). The focus on representational participatory procedures allows to account for both evolving empirical information as well as concomitant shifting values, norms, and judgments. Procedure provides flexibility as a means to handle the uncertainty.

As was pointed out, SAI research entails normative uncertainty due to the empirical uncertainty surrounding its outcome, as well as the political uncertainty of reconciling different values, based on the tacit metaethical assumption of some form of value pluralism. Participation and procedure can deal best with these uncertainties, given their focus on reflexivity and iteration, as well as their methodological agnosticism toward substantive ethical claims. However, the norm of participation in order to deal with normative uncertainty in climate policy has its own pitfalls of injustice, if it stays unqualified. For example, if we simply assume that justice is done if each country gets to have the same vote when a new climate policy is introduced, we fail to acknowledge the historical, socio-economic context of climate change. Unqualified, idealized participation can easily become a tool to perpetuate existing historical and structural injustices, by omitting the presence of underlying structural inequities.

In order to account for these pitfalls, some scholars have argued for the inclusion of recognition as a norm when it comes to climate justice and policy procedures. Recognition entails that the historical context of global power imbalances, based e.g. on patriarchal or racist-imperialist, neo-colonial politics, be taken as a background condition that needs to be accounted for in any decision-process. Justice as recognition within

the procedural sphere then focuses on the need to '[understand] differences alongside protecting equal rights for all, especially given the uneven capacity to exercise and defend rights'. (Newell et al., 2021, p. 6; see also Whyte, 2011)

In terms of the ethical assessment of SAI research, recognition plays an important role in avoiding the reification of current injustices, through 'paternalistic attitudes that have historically characterized relationships between the powerful and the vulnerable', (unwittingly) ignoring the potential dangers SAI research might impose (Hourdequin, 2016, p. 43). At the same time, recognition is well-suited to account for normative uncertainty, due to its deliberative and iterative nature. Recognition can help identify the prevalence of normative uncertainty arising in those value-pluralist, multi-lateral contexts.

Including recognition into the decision-procedure on SAI research avoids the imposition of a culturally specific set of norms (e.g. Western-centric approaches) onto the global community. For example, proponents of SAI research, David Keith and Joshua Horton argue that '[SAI] appears to be the most effective and practicable option available to alleviate a range of near-term climate damages that are certain to hurt the global South most of all'. (2016, p. 89) However, this framing of SAI as a remedy for climate injustices overlooks the fact that climate justice, on the authors' own account of dealing with the 'global poor', would call for much more radical adaptation and mitigation measures, e.g. in the form of global reparations and redistribution.¹⁷ In other words, this framing does not recognize the underlying structural injustices that underpin and exacerbate the harms of climate change.

The only way through which SAI deployment becomes the obvious candidate for redressing climate injustices, is if we assume a neo-liberal cost-benefit model, that accounts for climate harms in an a-historical context. These assumptions, in turn, could once again privilege those nations and communities already wielding most of the power, patronizing marginalized and vulnerable persons through the imposition of a specific set of norms in the decision-process. In other words, the failure to recognize and elevate the voices of those most impacted by potential SAI research leads to an exacerbation of injustices, not to their remedial. Such an approach would further seek to reduce the normative uncertainty, by implicitly claiming that a certain conception of justice, and a certain interpretation of the available data is to be prioritized over others.

At the same time, recognition must come from a place of respect and dignity if it is to account for justice in SAI decision-making (Hourdequin, 2019). In this vein, Olúfémi Táíwò and Shuchi Talati for example have cautioned that Western-based researchers, who call for a ban on SAI are themselves perpetuating colonial patterns by making choices on behalf of the global community (Táíwò & Talati, 2021). Similarly, the First Nations scholar and environmental ethicist Kyle Whyte points toward non-Indigenous environmentalists using Indigenous communities to argue for or against SAI research (Whyte & Buck, 2021). This form of 'present[ing] romantic accounts of Indigenous victimhood' (Whyte & Buck, 2021, p. 71) in order to make claims on behalf of Indigenous peoples, is an instance of misguided recognition in SAI research.

Thus recognition without respect and acknowledgment can easily be instrumentalized, especially in situations of normative uncertainty, where there are no unequivocal answers in terms of just outcomes. For this reason, recognition in procedural justice needs to be accompanied by some clear guardrails, if it is to account for normative uncertainties in SAI research.

VII. Qualifying Recognition and the Need for Normative Guardrails

Even an adapted, pragmatic concept of recognition cannot proceed without any ethical limitations, or otherwise normative uncertainty might open up space for radical relativism or nihilism. The fact that a group of decision-makers needs to account for different values and norms, which may at times be at odds with one another, does not yet incur normative uncertainty. Some values may be reasonable, based on conceptions of justice or well-being that can be justified, while others may not be. Normative uncertainty among decision-makers needs to be delimited by some shared fundamental guidelines, or principles, without being culturally imperialist or utterly relativist.

Regarding the international community, we can observe that there are some attempts of creating supposedly shared fundamental values, such as the Human Rights Charter, or the Sustainable Development Goals. Similarly, political philosophers have presented a variety of approaches that argue to capture all or parts of the human essence, on the basis of which they outline what individuals and communities should have access to¹⁸. What all these approaches have in common is to achieve justice – i.e. give an ideal outline of what justice could look like, and then seek to apply it to existing society.

In terms of uncertainty then, participants in a just deliberative process about SAI research need to consider what kinds of values should be part of a decision-process under NU, and what kind of values should not. For example, values based on imperialist efforts, racial and sexist discrimination and exploitation, or autocratic power motives should be excluded from a reasonably just decision-making process. In other words, a decision-space under NU needs to be delimited by ethical guardrails.

Guardrails throughout the decision-process would ensure two things. On the one hand, they would serve as limiting factors to what kinds of scenarios, futures, and data-interpretations are reasonable when dealing with ambiguity and value-pluralism. This is what Marion Hourdequin refers to as ‘basic respect’ (2019, p. 451), assuming the fundamental equality among persons and communities. Thus, SAI research programs need to ensure broad participation of all affected communities, appreciating the potential for different impacts. While the nature of the decision-process cannot account for all values, recognition would at the very least implore decision-makers to be clear about the values they choose to adhere to, and what kinds of moral considerations have been relegated or neglected. In this sense, recognition throughout the decision-procedure is a necessary condition for justice under NU in SAI research governance.

On the other hand, guardrails also free up the ethically justifiable space for argumentation, disagreement, and ultimately uncertainty. Accordingly, recognition does not only call for seeing other communities as equals, worthy of being included in the decision. Recognition also entails respecting important differences between communities (Hourdequin, 2019, p. 452) allowing for distinct cultural, societal, and moral consideration to play a role when evaluating a decision under normative uncertainty. Such respect requires to potentially accept norms and concerns foreign to one’s own value-system, creating a genuine space of open deliberation in a value-pluralist context. On this basis, guardrails create a free space of moral reflexion for policy-makers.

Note that these ethical guardrails should apply twofold. First, they should apply to the deliberative procedure itself, i.e. the process that seeks to explore SAI research. A possible instrument from deliberative democracy approaches are mini-

publics. These are small, representative citizen groups (see for example Bächtiger et al., 2018) that could serve as an avenue to account for the procedural and recognitional elements of justice with regards to SAI research. Through the intentional engagement of representative parts of the public, deliberation on the research of SAI could become more just, rather than merely focusing on expert judgment and modeling outcomes. It could also lead to a more nuanced form of gathering public opinion ('deliberative polls'), compared to traditional reflexive polling (Fishkin, 2009). Such a mini-public should ideally stay within such guardrails.

At the same time, mini-publics carry their own issues, by potentially upholding existing power structures unreflectively by virtue of the deliberative process that is still grounded in the unquestioned acceptance of political authority (e.g. Böker, 2017). In the case of SAI research, we can imagine that a mini-public might be used as a vehicle to further specific interests based on one-sided expert interpretations of data, which is especially relevant given the amounts of empirical uncertainty involved. Thus the guardrails need to also be applied to the creation of these deliberative spaces, so as to make space for critical reflection, especially if these deliberative spaces should be capable of designating exit-ramps and calling for the research to be stopped.¹⁹

The implementation of ethical guardrails sets up the playing field of reasonable ethical deliberation in the context of normative uncertainties when considering policy-decisions about SAI research governance. Delimiting such a space avoids the risk of simply justifying policies based on societal acceptance, highlighting the need for reflective ethical justifiability as well. (Taebi, 2017)²⁰ However, given the dynamic process of SAI research, another aspect needs to be taken into account when making decisions on SAI under NU, namely the processes' anticipatory and adaptive capacities.

VIII. Adaption, Anticipation, and Exit Ramps in SAI Research Governance

While a participatory and recognitional decision-procedure is able to account for the ethical challenges raised by normative uncertainty about SAI research, this approach alone does not yet outline how to practically implement such considerations. A policy-process is needed that allows for flexibility and revisions, and does not rely on static predictions of future outcomes.

Given the ambiguity under which SAI research would be planned, the process of making policies needs to be capable of revision and concomitant assessment. An ongoing research-process inevitably leads to new information, which in turn has to be included in the decision-making process on how to best proceed. SAI research governance is further a specific case, given its programmatic nature. Namely, an SAI research program would specifically aim to identify the technology's feasibility as a means to achieve a shared outcome (e.g. understanding why it's a bad idea²¹, or whether there are just pathways toward deployment – these are all questions that a deliberative process as described in the previous sections would need to answer). Given SAI's unique status of a 'non-existent /not-yet-existent' technology (Stilgoe, 2015), new information and insights are vital in defining its path, both for exploring its potential and realizing its flaws.

A suitable way to account for the normative uncertainty in the form of ambiguity is through adaptive planning. Adaptive planning entails that 'plans are designed from the

outset to be adapted over time in response to how the future may actually unfold' (Kwakkel & Haasnoot, 2019, p. 358). Specifically, the concept of 'Dynamic Adaptive Policy Pathways' (Haasnoot et al., 2013), could serve as an appropriate 'policy architecture' (Kwakkel & Haasnoot, 2019, p. 361), i.e. the overarching conception of how a policy plan could look. Instead of assuming a central research question and static plan, it allows for iterative reassessment and reiterations of the initial policy pathway.

The iterative nature of Adaptive Planning further gives space for ethical reflection and robust engagement with all parties affected by the policy. Scholars from STS and the ethics of technology emphasize the importance of a preemptive and ongoing ethical assessment of new and emerging technologies through e.g. Technology Assessment approaches (Grunwald, 2015), techno-moral scenario-building (Boenink et al., 2010; Hofbauer, 2022; Keulartz et al., 2004; Swierstra et al., 2009) or Responsible Research and Innovation (Stilgoe et al., 2013). Among these approaches, the emerging concept of Anticipatory Governance could be particularly suitable for the ongoing ethical assessment of SAI research governance.

Anticipatory governance is 'a broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible' (Guston, 2008, p. vi; see also Foley et al., 2018; Guston, 2014; Guston & Sarewitz, 2002). Anticipatory governance entails that decision-makers and publics are actively involved in the decision-process, and continuously evaluate, deliberate, and reflect upon the possibilities that a technology and its accompanying policy-decisions might produce. It thus allows for the reassessment of values, goals, and norms which guide the decision-process, while also being sensitive to the changes in the empirical understanding of the technology. By playing out 'what if ...?'-scenarios (Owen et al., 2013, p. 38) it is also specifically well-suited to deal with making decisions under normative uncertainty, exploring a plethora of scenarios and unexpected outcomes.

Adaptivity and anticipation should play a central role when it comes to SAI research governance, especially considering that SAI research may lead to the termination of strands of the research, or the entire program. This is necessary for a technology that is considered to be vulnerable to the development of unjust and harmful sociotechnical lock-ins. Such a lock-in situation of a SAI research program could unfold when institutionalized and vested interested (economic, political, etc.) create a research-context in which the original aim of learning more about the feasibility of a technology, turns into finding ways to create a pathway of eventual deployment. (Callies, 2019; Jamieson, 1996; McKinnon, 2019) This dynamic undermines ethically salient features of the decision-making process, by focusing on a- or immoral motives to continue the research.

In order to avoid such a lock-in, the NASEM's research governance proposal calls for the implementation of so-called exit-ramps, i.e. '[...] criteria and protocols for terminating research programs or areas' (National Academies of Sciences, Engineering, 2021, p. 9). Importantly, these ramps should be mechanisms that enable a swift termination of the research program. The qualification of these exit ramps also needs to be understood as an iterative process in and of itself, that is comprised both of recognitional deliberation and participation, as well as anticipatory and adaptive planning. Importantly, while some exit ramps may serve as guardrails themselves, by declaring certain research outcomes as morally

unacceptable (e.g. the risk of catastrophic outcomes, see Hartzell-Nichols, 2012), others may be adapted throughout the research process. Given the possibility of changing values and newly found information, exit ramps must be both robust in their application and dynamic in their assessment.

IX. Concluding Thoughts on SAI Research

Throughout this paper I sought out to explore what kinds of uncertainty will persist during the decision-making process on SAI research governance, and how these uncertainties affect the ethical assessment of such a potential governance project. I argued that current approaches tend to reduce uncertainty to either empirical or metaethical issues, which overlook the moral and practical dimensions of decision-making under what I have called normative uncertainty. Normative uncertainty, I argued, is a situation of ambiguous information and multi-lateral value pluralism that lacks unequivocal references in order to reach a decision. In order to deal with this normative uncertainty, I proposed the inclusion of recognitional, participatory justice considerations as well as adaptive and anticipatory governance methodologies.

While SAI research may produce invaluable insights on climate change beyond the technology itself, it must be stressed that even if feasible, SAI cannot be a solution to the problem of anthropogenic climate change. Importantly, any kind of SAI deployment cannot account for the underlying structural injustices that make climate change so harmful for so many in the first place, such as colonial land grabbing and displacement, climate racism, and the environmental exploitation for the monetary gains of a wealthy few. While SAI does not and cannot account for these injustices, a research program that seeks to reflect on the ethical assessment of such a technology should also be a space to reflect on the question *how it has come to this*.

Notes

1. Other common terms are: solar geoengineering, or just geoengineering/climate engineering. I use the term solar climate engineering, specifically focusing on Stratospheric Aerosol Injection.
2. also extrapolating from empirical data and observation made during the Mount Pinatubo Eruption in the early 1990s.
3. Whether we use the term modification or management is itself morally and politically interesting – do we control ('manage') or do we simply engage ('modify').
4. Note that not all scholars agree with this taxonomy (Buck et al., 2014).
5. Rayner et al. (2013) and Gardiner and Fraginière (2018) both blur the line between research and governance deployment, a point which Gardiner and Fraginiere make explicit (2018, p. 145). While this merits attention in and of itself, it goes beyond the scope of this piece to take into consideration.
6. 'Risks and uncertainties may be reduced, but not eliminated by research'. (National Academies of Sciences, Engineering, 2021, p. 116).
7. For a critical review of IAMs and their use in climate policy, see for example Frisch (2013).
8. In an earlier piece, Hartzell-Nichols applies her version of the PP to the case of SAI, stating that research might be justifiable, but deployment certainly not (Hartzell-Nichols, 2012). The author reaches this conclusion by exploring whether deploying SAI can be seen as a precautionary measure to fend of catastrophic climate change.

9. If one is a convinced vegetarian, there is of course no uncertainty about the matter. However, many struggle with the morality of eating animals, which makes this an illustrative example.
10. It should be noted the term ‘moral theory’ is used here in a very broad sense. It also includes everyday moral principles and norms such as the golden rule (‘Treat people the way you want to be treated’), for example.
11. For an in-depth treatment of the challenges for non-cognitivists with regards to normative uncertainty, see (MacAskill et al., 2020, chap. 7).
12. I would like to thank an anonymous reviewer for pointing out that this second dimension of moral uncertainty raises an important question, namely whether it is simply a reframing of the struggle of coming to a shared decision under conditions of value pluralism. ‘Moral’ uncertainty would then fundamentally become a ‘political’ or pragmatic issue. My response to this is twofold. One, value pluralism (e.g. in the Rawlsian sense) is without a doubt part of what produces the uncertainty. Namely, I tacitly imply a metaethically value pluralist stance, which should entail a sense of humility when trying to make value-laden choices with others, who hold different values than me. Second, value pluralism alone is not what leads to uncertainty in SAI’s case – it is crucially also the empirical uncertainty of ‘the facts of the matter’ and the political/pragmatist uncertainty that comes from the ‘messiness’ of having to reconcile and find compromise. Thus there is a combination of metaethical, empirical and political/pragmatic reasons for this dimension of moral uncertainty to arise.
13. I am – I think uncontroversially – assuming here a baseline of participation in the decision-making process as ‘ideal’. More on this in the subsequent sections.
14. Robert Nozick himself maintains that whether or not something is just, depends on the history of its acquisition and just inheritance (through, e.g. contractual agreement).
15. This can also refer to non-material, societal goods such as well-being, capabilities, or self-worth.
16. Fraser & Honneth’s notion of participatory parity also includes an ‘objective’, socio-material dimension. This dimension requires that all members of a society have the material, educational, societal, etc. means to actually meaningfully participate in a decision-process. (ibid 36ff).
17. I owe this reframing and critical understanding of Keith’s and Horton’s argument to an anonymous reviewer.
18. These approaches can be loosely understood as capability and function-based approaches, see for example (Nussbaum, 1990; Robeyns, 2006; Sen, 1987).
19. There remains a lot to be said on the construction of deliberative spaces, especially with regards to critical theory approaches. Thus the preceding section should merely serve as a means to exemplify how justice considerations could play a role in said construction.
20. Taebi (2017) and Taebi et al. (2020) usually refer to the Rawlsian Wide Reflective Equilibrium in order to account for ethical justifiability. However, I believe that the inclusion of recognition should be front and center when it comes to SAI, given its global nature. Whether or not recognition can be a part of a practical WRE process, could in and of itself be an interesting research question.
21. The motivation of having a research program to (also) prove its *infeasibility* tends to be overlooked, which I think should at least be a major question for SAI research.

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