RESEARCH PAPER

Techno-moral change through solar geoengineering: How geoengineering challenges sustainability

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ABSTRACT

This article brings a new perspective to the ethical debate on geoengineering through stratospheric aerosol injection (SAI), incorporating the emerging techno-moral change scholarship into the discussion surrounding sustainability. The techno-moral change approach can help us understand different ways in which technology might shape society. First, it helps highlight how values and norms are interrelated. Second, it shows that techno-moral change can happen even if the technology is in no way realized. Through the introduction of two techno-moral vignettes, two diametrically opposed ways in which SAI forces us to rethink sustainability and our relationship with nature are suggested. SAI could lead to a situation of entrenchment, wherein sustainability as a norm is undermined, or transformation where the necessity of acting according to sustainability is highlighted.

Introduction

Rapid global warming and climatic change have impactful consequences for nature and humanity. Slow political action and insufficient policies, combined with the increasing and unpredictable threat of climate change challenge current ways of living. Industrialized societies appear to have ended up in an unsustainable situation (i.e., the resources consumed by human beings are outweighed by their rate of reproduction).

To overcome this unsustainability, scientists, scholars and policymakers are considering technological solutions in the wake of realizing just how far-reaching human impact on the climate and the environment is. The idea is that technology can help societies be more sustainable, as the European Green Deal exemplifies with its heavy focus on research and development of green energy production and storage (European Commission, 2019). Framing climate change as a technological problem rather than a behavioural one evokes the term 'techno-fix' (Weinberg, 1966). Since it is difficult to implement behavioural changes through policy, societal issues are supposedly 'fixed' through technological development (cf. Huesemann and Huesemann, 2011). Achieving sustainability becomes a purely technological task, rather than a societal one.

One particularly prevalent example of this is the idea of geoengineering, intentionally manipulating the earth's climate through technical means (Keith, 2001). There are different ways of engineering the climate (for an overview, see Shepherd *et al.*. 2009). However, focus here is on one particular form, namely stratospheric aerosol injection (SAI) (Crutzen, 2006; Keith, 2013; Tilmes *et al.,* 2020).

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In short, SAI entails spraying aerosols into the stratosphere, which reduces some of the incoming sunlight, cooling the earth's surface temperature. Some consider the technology as a possible way of buying time to reduce parts of the most dangerous climate change impacts in the upcoming decades. At the same time, it is generally agreed that the technology is not a silver bullet solution to climate change (Keith, 2013; Horton and Keith, 2016; Svoboda *et al.,* 2018)

The topic of SAI has received growing attention from the fields of science, technology and society studies, ethics and political philosophy in recent years (for an overview, see Stilgoe, 2015; Pamplany *et al.*, 2020). Throughout the debate on the ethics of SAI, a specific focus is usually on issues of historical, procedural and distributive justice (Preston, 2016). If sustainability is taken into account when discussing SAI, it is in order to make a point about its unsustainability (Adloff and Hilbrich, 2021), or how the sustainability debate can bring different viewpoints on SAI together (Thiele, 2019). How SAI potentially affects conceptions of sustainability, however, is underdeveloped. This article seeks to fill the gap on how SAI as technology can lead to techno-moral change (Swierstra *et al.*, 2009). Focus is on the norm of sustainability and how SAI affects this norm and the underlying value of nature.

The article is structured as follows. First, the concept of techno-moral change and how it can be used to build scenarios of technological futures is outlined. The ethical debate on SAI so far is discussed in the context of the argument that there is little interest in the techno-moral impact of SAI beyond the so-called 'moral corruption' claim (Gardiner, 2010). The next section builds on this criticism, establishing the relationship between technological development and sustainability. In so doing, it is argued that SAI is of particular interest for this relationship because of the technology's direct connection to climate change. With a focus on the value of nature, the article moves on to how SAI forces society to question our relationship with nature. Two short techno-moral vignettes, namely Entrenchment and Transformation*,* illustrate how SAI could change our perception of sustainability and nature. My main argument is that techno-moral change can help us understand different ways in which technology can shape society, how values and norms are interrelated and that the impact can happen even if the technology is not realized.

Techno-moral change

Technology and its development have an impact on society, morality and the realm of the political, as discussed throughout the philosophy and ethics of technology (Winner, 1980; Verbeek, 2011; Grunwald, 2015). Over the past decade, scholarly interest has focused on how technologies mediate and influence ethical norms, values and concepts. Such a focus entails an emphasis on co-dependent evolution, where society evolves with the technologies it creates. This field of research is commonly referred to now as 'techno-moral change' (moral change brought about through technological development) (Swierstra *et al*., 2009; Swierstra, 2013; Nickel *et al.*, 2022).

The scholarship of techno-moral change (TMC) is based on Deweyian pragmatism and the field of science, technology and society (STS) studies, with the aim of including normative considerations into them (Keulartz *et al*., 2004). In pragmatic fashion, TMC opposes ethical foundationalism. It does away with the idea that an ethics of technology should seek universal moral values or truths. Rather, TMC highlights the dynamic character of modern, pluralist societies, which are constituted by continuous technological development, and zooms in on how technology impacts moral values and norms (Boenink *et al.,* 2010; Swierstra and te Molder, 2012).

To understand better what precisely changes when TMC occurs, Tsjalling Swierstra's framing of morality as a force field is helpful (Swierstra, 2013). In a pluralist society, there is a constant underlying debate on what kinds of norms and values, which are different subsets of morality, should be acceptable. As an example, we can think of how Roman Catholic morality competes with secular feminist morality, both of them with their respective norms and values. TMC occurs when the introduction of a new technology tips the scale of the competition in favour of one morality.

The norm of chastity and the value of virginity lost footing in many societies, in part, as a result of the technological development of the contraceptive pill.[1]

At heart, techno-moral change occurs through the coevolution of technology and society (Rip and Kemp, 1998). Technology influences societal norms, for instance, by making 'some moral options easier to argue for and others less easy', as the example of the contraceptive pill shows (Swierstra *et al.*, 2009, p.120). By opening up new courses of action and closing off others, technology changes how one can behave in a given situation. Technology might make it easier to do the right thing by changing our range of options or motivations. This is most explicit in so-called 'behavioural change' technologies that give us direct feedback on our actions, and try to nudge us into certain habits (Frank, 2020).

Similarly, technologies can afford and constrain actions that realize certain values (Brey, 2005, 2018). For example, prenatal diagnostics allow parents to know about the state of health of their child before giving birth, affording them a range of previously unattainable moral options. Thus, whether to give birth to a baby with certain health conditions becomes a choice rather than the acceptance of fate. Accordingly, technology mediates how we perceive the world and ourselves and alters the range of possibilities for action and deliberation. Ultrasound imaging positions expecting parents as decision-makers who deliberate on the basis of the expected health of their unborn child (Verbeek, 2011). The technology forces a whole range of new ethical questions onto the parents (e.g., on what basis to evaluate whether a child is worth having, whether to know, or want to know, about potential health concerns).

Realizing that technology actively shapes morality is insightful when it comes to the evaluation and analysis of existing technologies after their deployment. This is especially interesting since norms and values are not isolated from one another, meaning that a change in one of them often entails a change in others (Swierstra, 2013). This interdependence of norms and values is best showcased by unforeseen consequences of new technologies. Again, one can look into how the introduction of the contraceptive pill supported the feminist movements in the 1960s and 1970s (Baker, 2019; Nickel *et al.*, 2022). While the pill allowed for more sexual freedom, it might simultaneously be argued to have shifted the burden of taking care wholly onto women in terms of unwanted pregnancies. Whether and how contraception is made technically possible accordingly entails new possibilities – and burdens – for a society and its individuals.

Another interesting example of techno-moral change is the introduction of mechanical ventilators during the 1950s. This technological innovation caused widespread moral uncertainty about whether withdrawing ventilation from brain-dead patients is morally permissible since it was unclear whether this would constitute murder (Baker, 2013, 2019; Nickel, 2020). Before the use of mechanical ventilation, a person was simply considered to have died when the brain no longer supported breathing. As a result, the heart would stop beating, leading to death. However, it was possible to continue circulation and a beating heart through external means with this new technology. Thus, while the patient's brain stopped functioning, the heart was still beating, leading to the necessary introduction of a new concept of between life and death – brain death. This example highlights how the introduction of new technologies can be disruptive to a set of moral norms, calling into question concepts previously thought to be relatively stable, such as death.

However, it is arguably insufficient from an ethical point of view to understand the moral implications of a technology only after its implementation. Especially in terms of policy-making and governance for new and emerging technologies, it is even more critical to understand the potential impact *ex ante*. The burning question is to understand how research and deployment of certain new technologies affect morality and underlying societal norms before deploying them. In this vein, Taebi and colleagues have explored a framework to account for the development and deployment

[1]Of course, voices of change, resistance and social movements are at least as, if not more, important for moral change (Anderson, 2014; Baker, 2019).

of new and emerging technologies in the face of the climate crisis (Taebi *et al.*, 2020).[2] Specifically, they focus on how different kinds of uncertainties can arise, such as how public values might change over time.

Accounting for uncertainty thus acts as a safeguard in dealing with all possible kinds of futures. Developing taxonomies and frameworks that consciously include the uncertainties surrounding new and emerging technologies is only one aspect of the solution. The other aspect of dealing with techno-moral change is through the building of scenarios, imagining how the future might change in terms of values and norms. Anticipating or predicting these and how the future will play out is a near impossible task. This holds true also for the effects of technological innovation on society, in which case the relationship between prediction and deployment is in itself a vexing issue. The time when a technology is most malleable (i.e., design and development) is also when its impacts are most uncertain. Once the impacts manifest themselves through the gradual introduction of the technology, its malleability is drastically reduced since it is difficult (if not impossible) to change retrospectively anything about the technology (Collingridge, 1980). This interrelation between uncertain futures and technological development can be found throughout the ethics of technology and geoengineering in the form of the Collingridge Dilemma, lock-in or path-dependency (Cairns, 2014; Genus and Stirling, 2018).

The apparent predicament of not being able to predict the future, however, does not entail openness towards all possible futures. How the future develops is itself based on values and ideals of what should and should not be part of the future. What events or dangers call for pre-emption or precaution, or what society needs to prepare for, are all present considerations that shape the future (Anderson, 2010).[3] Societies are based on imaginaries that project ways of living from the present into the future (Taylor, 2004; Jasanoff and Kim, 2015), and expectations of how the future should or will turn out manifest themselves in the present through experts, research programmes and institutions (Hilgartner, 2015; Sand, 2018). The future is not a value-neutral field of possibilities, but a space of negotiation for possible scenarios of moral change.

With this in mind, predicting a technology's moral impact becomes less important for its evaluation. Instead, one can focus on how the competing values and norms might be influenced by technological development through a process of scenario building, or techno-moral learning (Swierstra, 2013). In order to understand the impacts that nanotechnology might have at a societal level, Swierstra (2013, p.216) writes that we need to 'train our capacities for techno-moral imagination by developing scenarios and vignettes'. This form of scenario building can help anticipate the societal impact of new and emerging technologies, adding potentially fruitful new points of view to a decision-making process otherwise difficult to determine. The goal of such imagining is not to predict outcomes but rather to illuminate possible future scenarios. Although these moral scenarios might not occur as imagined, certain aspects of them can nonetheless help us understand what kind of values and norms a new technology influences and how.

Solar geoengineering through stratospheric aerosol injection

Geoengineering can be understood as an attempt to deliberately counteract the human impact on the climate through technological means (Keith, 2001). There are several ways of engaging in geoengineering, ranging from high technology proposals, such as mirrors in space, all the way to seemingly natural or harmless solutions. such as increased afforestation or painting rooftops and roads white (Shepherd *et al.,* 2009).

Since the Royal Society's report on geoengineering, it has become commonplace within the literature to distinguish between two main strands of geoengineering, namely carbon dioxide reduction (CDR) and solar radiation management (SRM) (Shepherd *et al.*, 2009). The main difference

[2]I am indebted to an anonymous reviewer for pointing me towards this paper.
[3]I would like to thank an anonymous reviewer for making these connections.

between the two approaches is that CDR aims to reduce the current amount of atmospheric carbon, hence the removal. By contrast, SRM approaches seek to increase the planet's reflection levels, reflecting more sunlight back into space before it can heat up the atmosphere.[4]

One way of achieving SRM is by spraying aerosols into the atmosphere – so-called stratospheric aerosol injection (SAI) – which would increase the earth's reflection levels and subsequently reduce surface temperatures (Niemeier and Tilmes, 2017; Shepherd *et al.,* 2009). SAI, therefore, represents a technology that could potentially aid humanity in the fight against climate change.

With this backdrop in mind, the question of how a technology such as SAI can impact current societal norms and values arises. SAI is being discussed within the ethics literature, usually focusing on its implications for different questions of justice, ranging from participatory, distributive, to historical, post-colonial and feminist notions (Preston, 2013; Buck *et al*., 2014; Horton and Keith, 2016; Whyte, 2018). These discussions do not focus on the moral impact in the sense of techno-moral change that SAI could have on society.

One exception is Stephen Gardiner's argument for moral corruption, recently reiterated and refined by him, and Augustin Fragnière (Gardiner, 2010; Fragnière and Gardiner, 2016). Originally the argument was aimed at the claim that current generations have a responsibility to research SAI for future generations to have access to it. Gardiner criticizes this, claiming that even researching a technology such as SAI could have a troubling impact on a shared sense of responsibility for dealing with climate change. By putting resources into the research of a highly risky and uncertain technology, current generations might consider their fair share of climate action achieved, arming future generations with the know-how of how to use SAI in an emergency (Betz, 2012).

However, according to Gardiner, this would represent a perversion of the norm of responsibility. By framing SAI research as a means of equipping future generations with this technology, 'we – the current generation, and especially those in the affluent countries – are particularly vulnerable to moral corruption, that is, to the subversion of our moral discourse to our own ends' (Gardiner, 2010, p.286). Although not explicit, the claim that merely researching a new technology can subvert an entire moral discourse is clearly an argument for techno-moral change, albeit in the form of techno-moral regress perhaps.[5]

While SAI potentially forces sweeping techno-moral changes of different kinds of norms of values, this article focuses on one norm, namely sustainability and the underlying value of nature. There are two reasons for this. One, sustainability is a central theme when discussing technologies that are aimed at alleviating the impacts of climate change. In contrast, continuous development, growth and innovation can be seen as one of the reasons why current industrialized societies are unsustainable. Two, sustainability is a norm that draws its justification from the necessity to account for the value of nature in the face of expanding human environmental impact. The ways in which technology might impact our perception of nature are especially stark in the case of geoengineering, while at the same time geoengineering is in some way considered to protect nature. This seemingly contradictory relationship makes sustainability and nature ideal candidates for the investigation of techno-moral change through SAI.

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[4]It should be noted that some authors challenge this taxonomy (Buck *et al.*, 2014; Smith, 2018), arguing that the risk (or the gendered difference between care and domination) involved in deploying the different methods would be better suited to distinguishing between them. For the sake of brevity, this article adheres to the Royal Society's taxonomy.

[5]Whether this fear of moral corruption is justified is difficult to answer, and requires both empirical and conceptual work. It should be noted, however, that surveys regarding public awareness of solar geoengineering tend to increase individual commitment to climate action, rather than decrease it (Merk *et al*., 2016; Cherry *et al*., 2021). In a recent book, Gernot Wagner also argues that researching solar geoengineering could be a good way to scare people into more stringent climate policies (Wagner, 2021).

Sustainability and technology

We think about sustainability in the context of technology because of the predicament of striving for continuous growth and welfare on a planet with limited resources. With the Brundtland report in 1987, the notion of sustainable development gained traction as a necessary condition for equitable growth and well-being on a global scale (Brundtland, 1987). The necessity for sustainable development instead of merely development came on the back of the realization that continuous and unregulated economic growth would eventually overburden the earth's ecosystem (Meadows *et al*., 2013). The idea of planetary boundaries served to highlight this predicament, pointing out that growth must respect both ecological and societal limits.

Squaring economic growth and affluence with other values, such as nature, is expressed in the I-PAT equation. The environmental impact (I) consists of the population of a given nation (P) times its affluence (A) times its technological efficiency (T) (Ehrlich and Holdren, 1971; Holdren and Ehrlich, 1974). Since decreasing populations or affluence seem political non-starters, reducing environmental impact is possible only through technological innovation.[6] This, in turn, brings innovation and growth into an interesting relationship with sustainability, challenging the traditional opposition between innovation and de-growth (Pesch, 2018). The paradigm of economic growth often describes sustainability as an innovation challenge. From this perspective, the solution to increasingly unsustainable ways of life is not a change in behaviour or economic systems (e.g., capitalism). Rather, sustainability is to be achieved through technological innovation, which is coupled with, instead of juxtaposed to, economic growth.

In contrast, paradigms of de-growth challenge the ideal of continuous economic growth. While growth is often coupled with innovation, one can also imagine how innovation within the ICT sector, such as in decentralized forms of communication, can lead to effective de-growth and an increase in sustainability. The seemingly paradoxical relationship between growth and de-growth becomes clear when technological development is tied to the notion of reduction and decentralization rather than expansion (Pesch, 2018). Based on this, one can see how technological development becomes an important instrument to realize sustainability under current circumstances. The connection between technology and sustainability can thus be summarized in terms of being both complex and necessary. While the quest for never-ending economic growth can be considered to be a bane to sustainability, growth that enables sustainable innovation might prove vital in dealing with certain unsustainable practices. At the same time, technological development changes what can be considered sustainable, by changing our perception of nature.

Nature, sustainability and SAI

When researchers propose ways of geoengineering, they usually do so to protect both human beings and the environment, or nature, from climate change. This implies that to be more sustainable, humanity should increase its impact on nature, rather than step back from it. This tacit endorsement of human control over nature is paramount to understanding the relationship between nature, sustainability and SAI. Taking control over nature is argued to be a shift from past to modern technologies by such philosophers as Martin Heidegger (1977) and Hans Jonas (1984).

> Unspoken, but self-evident for those times [antiquity], is the pervading knowledge behind it all that, for all his boundless resourcefulness, man [sic] is still small by the measure of the elements: precisely this makes his sallies into them so daring and allows those elements to tolerate his forwardness.

[6]Apart from the political reasons, there is another argument for neglecting the factor of population control when accounting for environmental impact, as can be seen in the immense inequalities in terms of who emits how much. When tied to wealth, the richest 10% of the planet was responsible for close to 50% of annual emissions in 2015 (Kartha *et al*., 2020). Also, note that both Holdren and Ehrlich acknowledge that population growth and increasing affluence are a central issue for environmental degradation (see, e.g., Holdren, 2018).

> Making free with the denizens of land and sea and air, he yet leaves the encompassing nature of those elements unchanged and their generative powers undiminished. He cannot harm them by carving out his little kingdom from theirs. They last, while his schemes have their short-lived ways. (Jonas, 1984, p.3) [7]

The first realization we have to have as modern human beings is that we no longer leave the encompassing nature of land, sea and air unchanged. Instead, by carving out our little kingdoms, humanity has had an infamous impact on the planet, most prominently (though not exclusively) through climate change.[8] Furthermore, and most pertinent in terms of sustainability, our schemes seem to last and thus affect the plant, animal and natural kingdoms even more violently.

In this view, nature is the clearly distinguishable other, separate from culture and humanity (cf. Vogel, 2015; Latour, 2017). What makes modern technology, and specifically geoengineering through SAI, particularly contentious is its active and intentional intervention in the climate system, breaking the boundary between the natural and the artificial. Although climate change has been considered an experiment of unprecedented scale itself (Revelle and Suess, 1957), there is a fundamental difference from what SAI entails, the intentional making of a new climate. By deploying SAI, '[t]he climate would become artificial in the literal sense of becoming an artefact – a product of human endeavour' (Hulme, 2014, p.95). This concept of 'arteficiation' has significant consequences for the value of nature in terms of sustainability.

On the one hand, the arteficiation of the climate seems to be an intuitively hubristic and thus unacceptable undertaking. The risks are simply too high, and the disregard for nature and the environment too brazen. From this perspective, SAI represents the final frontier of the eco-modernist endeavour, disregarding nature and anything non-human unless it can serve anthropocentric ends. Whatever is deemed sustainable is so because it upholds and furthers human interests. Nature is to be dominated through technology and must bend to humanity's will. The discourse of domination is at the very least echoed in the idea of SAI building on imaginaries of Cold War era power fantasies (Stilgoe, 2015). It is further reminiscent of mechanistic conceptions of nature, wherein domination of men over nature is central to any scientific undertaking. In this regard, SAI also calls for an ecofeminist perspective that is able to take into account the deeply gendered aspects of its science and discourse (Buck *et al*., 2014).

On the other hand, the reality of climate change makes denying human beings' prominent role in shaping the planet hard to dismiss. Taking the responsibility that comes with this influence seriously leads to the idea of planetary stewardship, accepting responsibility for the power humanity has accrued (Steffen *et al.*, 2011). Leslie Thiele (2019) highlights this idea when trying to bridge the gap between the staunch opponents of SAI ('Gaians') and tentative proponents ('Prometheans') through the concept of sustainability. Thiele (2019, p.475) argues that SAI could be perceived as a 'regrettable but necessary means for our species to regain the status of nature's ally, rather than go down swinging as her arrogant opponent'. Whether as Gaians or Prometheans, SAI as a technology forces us to be clear about what can and cannot be sustainable, and how we position ourselves towards nature, our environment and the non-human. We can identify this as a form of techno-moral learning (Swierstra, 2013), in that there needs to be a societal re-evaluation of what nature means when its very existence is put into question through new and emerging technologies. More specifically, it forces us to ask what we can consider sustainable, and what sustainability entails.

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[7]Jonas is not referring to geoengineering, but rather gene-editing and the destructive force of nuclear power.
[8]Though not unconnected, the influence modern human beings have had on the nitrogen cycle can be considered equally impactful (Jenkinson, 2001)

Two techno-moral vignettes

So far we have established a connection between technology and sustainability, how technology is relevant to achieving sustainability, and how both relate to the value of nature. In order to analyse SAI on the basis of techno-moral change, this section explores how the research and potential deployment of SAI can change the norm of sustainability and the value of nature. To give an outline of how SAI could shift our understanding of a sustainable future, it is useful to distinguish between two kinds of sustainability: entrenchment and transformation. Sustainability as entrenchment is the idea of continuing on the current trajectory of the eco-modernist project, focusing on finding an 'ecological balance of modern societies by means of technological and social innovation' (Adloff and Neckel, 2019, p.1018). This is entrenchment since there are no fundamental changes in how a society is organized or in the values and norms it exhibits. Rather, basic market systems (such as capitalism and consumer societies) are taken for granted, while certain elements are tweaked in a piecemeal fashion to deal with arising issues.[9] To illustrate this distinction, I engage in a type of downscaled scenario building in the form of two short techno-moral vignettes from some point in the future (Keulartz *et al*., 2004; Boenink *et al.*, 2010) after SAI has been deployed. The two vignettes should be understood as diametrically opposed extreme cases of TMC.

Scenario one: entrenchment

It's been ten years since the first fleet of *Veilmakers* (Morton, 2015) lifted off. Temperature rise has been stabilized, only increasing at a prolonged rate, and CO_2 levels have peaked. Media outlets, politicians and a swath of the public are celebrating the defeat of climate change. People live their lives, as usual. The EU's goals of complete decarbonization have slowed, so have the commitments by the US, India and China. Now that the easier parts of decarbonization have been achieved, any step further involves a great effort that is no longer economically feasible since it is easier simply to put more aerosols into the stratosphere. Those calling for structural changes are framed as climate alarmists with hidden ideological agendas – after all, technology found a way out for us! One can only imagine the pointless suffering had society made all those changes in 2021. Instead, Jeff Bezos and Elon Musk have brought together a group of billionaires who vowed to keep up the veil, assuring the general public that the termination shock was always just an unreasonable scare tactic.

This first vignette is an imaginary representation of the potential moral corruption that SAI might cause (Gardiner, 2010), taken to a polemic extreme. Opponents frequently use this possibility of entrenchment to argue against SAI (Hulme, 2014; Schneider, 2019; Dryzek and Pickering, 2019). Resistance towards SAI often entails opposition to current global power structures and economic systems. Arguing in favour of SAI is akin to defending a failed status quo (Schneider, 2019). Similarly, John Dryzek and Jonathan Pickering dismiss SAI on the basis that the infrastructure and institutions necessary to support the technology would have to be 'global, paramount, and permanent', foreclosing any other future developments (Dryzek and Pickering, 2019, p.53). The apparent impossibility of 'coming back' from a geoengineered climate makes it all the more dangerous.

Frank Adloff and Iris Hilbrich add the concept of 'control' to discuss geoengineering and concepts of sustainability (Adloff and Hilbrich, 2021). They conceptualize geoengineering as a way to enact control over nature, as the eco-modernists seek to solve pressing issues of climate change and societal problems through technological innovation (Adloff and Hilbrich, 2021, p.177). This view of geoengineering can be expanded through Dale Jamieson's argument that human beings value nature because of its autonomy: '[W]hat we value in nature is that she "does her own thing" and is largely indifferent to us' (Jamieson, 2008, p.166). Following this line of argument, one might conclude that SAI is the negation of this autonomy, enacting control rather

[9]This approach is reminiscent of Karl Popper's outlook in *Open Society* (Popper, 2008).

than allowing for autonomy. From this we can summarize that control over the climate necessarily entails eliminating nature's autonomy, which is what is valuable about nature in the first place. The norm of sustainability in times of geoengineering through SAI seems to lose all meaning, if it is to stay at all connected to nature.

However, a nuanced approach can put SAI into a more positive light in the form of planetary stewardship (Steffen *et al.,* 2011). Realizing the lasting impact human societies have on their surroundings can also entail realizing a special kind of responsibility to deal with these impacts. As Steffen and colleagues point out, 'We are the first generation with the knowledge of how our activities influence the Earth System, and thus the first generation with the power and the responsibility to change our relationship with the planet' (Steffen *et al.,* 2011, p.749). From this perspective, thinking about SAI as a partial, incremental step towards dealing with and perhaps reducing the negative human impacts becomes morally necessary. In addition, the fact that such technologies are being considered could have a transformative effect on current societal understanding of nature and consequently the norm of sustainability. It could serve as a techno-moral catalyst for moral learning. The second scenario explores this.

Scenario two: transformation

It's been ten years since the first fleet of *Veilmakers* (Morton, 2015) lifted off. Temperature rise has been stabilized, only increasing at a prolonged rate, and CO_2 levels have peaked. Despite the apparent victory, one can sense a reluctance for celebration. 'The veil can only keep us safe for so long – we need to act now!' reads a famous newspaper's headline. Alongside the decision to deploy SAI, most nations on the planet have agreed to increase their efforts on not just complete decarbonization, but the active reduction of atmospheric CO_2. Since the veil has been up, there has been an increased public push towards radical mitigation. 'We are just suffocating ourselves if we don't follow this up with carbon sequestration', a leading climate scientist is quoted as saying. 'This is just the beginning of our shared effort'. The reality of geoengineering has also made people sensitive to broader societal issues, especially income and wealth inequalities within and between nations. The veil has made people become more aware of the climate as a shared, living and breathing space. Many countries are working on implementing deep-cutting wealth taxes, while private jets and yachts have been banned. Obviously, there is no place for this absurd luxury on a planet that is undergoing chemotherapy.

Transformation represents a future wherein deployment has underscored the necessity to become more sustainable, enforcing rather than undermining sustainability. Here, SAI and its impact on sustainability are considered to be a catalyst for societal moral change. At heart, transformation entails broad-sweeping societal changes, including behavioural and institutional adaptions. The necessity for these changes comes from a shared understanding that 'the natural and social foundations of life on earth will not be protected by means of a further economisation of sustainability' (Adloff and Neckel, 2019, p.1020)

Proponents of SAI seem not to be explicit about the question of entrenchment/transformation, although virtually all scholars talking about SAI emphasize the inevitable need to move towards a carbon-zero future. From their perspective, doing the research is a necessary precursor to learning whether it should be done or not (Wagner, 2021; cf. Hamilton, 2013b). One of the most prominent researchers on SAI, the physicist David Keith, further argues that deployment could be undertaken incrementally and only to the extent that it offsets half of the increased global warming. This would allow for monitoring progress, aborting deployment if necessary and thereby facing less risk and potential damage. Secondly, it would give a strong incentive to continue with radical mitigation (Keith, 2013, p.23).

Critics will be quick to point out that such an application of SAI is unrealistic and that Machiavellian instincts will have politicians rather increase rates of aerosols sprayed than carbon dioxide reduced or mitigated (Hamilton, 2013b). For them, SAI is a technological instrument that

would further entrench existing injustices and undermine the norm of sustainability. However, this conclusion is neither logically necessary nor empirically obvious, but rather based on a pessimistic projection of how the future will develop. Transformation is an equally plausible outcome of entrenchment. However, different, implicit ways of determining what sustainability is have been reached. While entrenchment clearly sees sustainability and its accompanying values as a way of continuing current power structures, transformation leads to a holistic conceptualization of sustainability, whereby the norm becomes a necessity to uphold, protecting nature for its own sake.

It is important to keep in mind that these vignettes do not try to produce an accurate prediction of the future, nor do they serve as full-blown scenarios to be evaluated (although they could serve as a starting point for such scenario building). Rather, they serve two purposes relevant for the anticipation of societal change through new technologies. First, these vignettes of techno-moral change contextualize norms and values and show how they do not exist in a vacuum (Swierstra, 2013). Second, they encourage ethical reflection by stimulating our 'moral imagination' (Swierstra *et al*., 2009). In an attempt to realize and possibly overcome moral biases based on current standards, such a form of moral imagination allows for an anticipatory view of how society might develop through a specific instance of techno-moral change (TMC). At the same time, it forces us to confront current trajectories from a self-reflective angle: is the path we chose a good one, based on the possible futures we face?

How do we assess techno-moral change?

Taking a step back, one can ask after the preceding discussion what techno-moral change as a theoretical tool can tell us about the relationship between SAI and sustainability or, put differently, how a new (and physically non-existent) technology impacts a shared understanding of what ought to be of value and how to realize this value. To assess this, recall Swierstra's (2013) interpretation of morality as a force field wherein interrelated norms and values compete for societal implementation.

Entrenchment and transformation represent two different force fields of morality. Entrenchment takes the status quo for granted. There is no reason to implement fundamental change. Humanity's environmental impact is simply something to be taken into account for anthropocentric ends and does not change how we view nature. Nature is a thing to be handled for the sake of humanity and, as long as it serves human ends, any action is permissible. What is sustainable is defined by how far humans can go in using natural resources in order to carve out their empires.

In contrast, transformation represents a more radical shift from current norms and values, changing from a business-as-usual instrumental and exploitative view of nature to a caring and self-reflected perspective. The change in how nature is viewed in transformation also impacts the idea of what is or is not sustainable. While SAI might sustain our way of life for now, more is necessary (e.g., implementing a wealth-tax, redistribution of resources, political and institutional changes) in order to act sustainably. Sustainability becomes a holistic framework for evaluating not only our use of nature as a resource, but the value of nature itself.

With this in mind, there are two lessons we can draw from the process of techno-moral change through SAI. First, TMC highlights the malleability of norms and values through new societal and technological contexts. The case of SAI forces a societal confrontation of what the norm of sustainability and the value of nature mean, and whether that norm is to be followed, and that value to be realized. New technology allows (or necessitates) new kinds of behaviour, and societal norms are often quick to adapt. In this sense, technologies can tip scales in favour of certain moralities. However, it is not always clear *ex ante* which morality will end up benefiting from the impact. As the two vignettes exemplify, the impact could go either way in terms of how the norm of sustainability can be understood.

What we can take from this discussion is that TMC and the process of techno-moral learning do not necessitate the actual implementation of a new technology. SAI and geoengineering in general are very much imaginary technologies (Stilgoe, 2015). SAI exists in computer models and

their empirical feasibility is drawn from inferential evidence through volcanic eruptions. Yet there is still the possibility of drawing moral lessons from the fact that these technologies are being considered in the first place, and that potential future scenarios include their deployment. The case explored here forces us to think about sustainability through technology in an age of unprecedented human impact on nature. While evaluating these potential futures of sustainability lies outside the scope of this article, the discussion has illustrated that TMC and techno-moral learning are not just means to project the future, but also mirrors of current societal and technological trajectories.

Conclusion

This article aims to explore techno-moral change through SAI, with a focus on how technology impacts the norm of sustainability and its accompanying value, nature. It seeks to connect technological development with the increasing necessity to act sustainably. It also tries to focus on the connection between how different ways of perceiving nature influence our understanding of sustainability and vice versa, highlighting the interdependent relationship between the norm of sustainability and the value of nature. To explore how conceptions of sustainability and nature might change through SAI, it presented two diametrically opposed views of SAI's techno-moral impact. Exploring this impact has shown two things. First, techno-moral change can go either way; it could either undermine or underscore the necessity of a sustainable future. Second, a technology does not have to be developed to have this impact. That it is being discussed as a potential future means of dealing with climate change might be enough to force techno-moral change.

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