6 Ways of seeing intervention and control

> When we talk about SRM, we try to be reluctant. But we also have to acknowledge that with an airplane, many substances are released into the atmosphere that we don't really know what they are doing. Lately I have been thinking about the reluctance I feel every time SRM methods are discussed, and how little thought I devote on the substances released whilst I'm taking a plane.
>
> (Researcher P)

> The idea of deliberately manipulating the climate with rudimentary technology based upon previous experiments is novel. The very idea of it introduces a lot of challenges in terms of how we think about ourselves as a species, as a civilisation, and what our relationship is and ought to be to nature—however you want to define it. It really changes the terms of our relationship with the material world in ways that aren't entirely clear at this point. It scrambles things.
>
> (Researcher 12)

Introduction: 'climate engineering is *undesirable*, ungovernable, and unreliable'

The Northern Irish Neil Harbisson, a self-proclaimed cyborg activist, is a curious character. In 2004, Harbisson connected an antenna to his brain. Born colour-blind, Harbisson uses the antenna, protruding from the top of his head, as a sensor that translates colours into sensations. Because Harbisson feels his black and white vision also gives him advantages over colourised sight, he opted to use the sensor as a *new* sense instead of using it to solve his colour-blindness. Over the years, Harbisson incorporated many more electronic technologies into his body—such as an internet connection for his antenna through which people can send images into his brain and Bluetooth communication in his teeth. As a result, he has become a vocal and controversial advocate for cyborgism. By his own account, many people perceive him as one of the most inspiring people his audience has encountered, but he also receives frequent death threats. In the eyes of his critics, Harbisson's tinkering goes against humanity, against God even (Verhagen, 2018). In his own way, Harbisson embodies the increasing entanglement between natural systems—in his case, the human body—and technological systems. He is controversial because his choices represent complex questions about to what extent human interference in biological systems is justifiable. Where Harbisson argues for the minute and the personal—a voluntary choice to alter one's *own* body—large-scale technological interventions, such as climate engineering, raise similar moral questions on a global scale. To many, furthering such entanglement between human technologies and natural systems is an exciting prospect—even on a systemic level. In 2016, for example, the annual meeting of the World Economic Forum (WEF) in Davos,[1] Switzerland, excitedly touted the 'fourth industrial revolution'. According to the WEF, the revolutionary potential of information technologies and artificial intelligence presents a tremendous opportunity for economic growth and prosperity around the world. Like Harbisson, such enthusiasm is controversial. As the *Washington Post* astutely noted, excitement about a fourth industrial revolution is ironic when unintended destructive consequences of previous industrial revolutions, such as plastic pollution and anthropogenic climate change, are not adequately dealt with (Kaplan, 2016). As the WEF *itself* had warned in the weeks leading up to their 2016 meeting, by 2050 plastic waste in the oceans could outweigh fish on a pound-for-pound basis (World Economic Forum, 2016). Enthusiasm about a fourth industrial revolution is also problematic when both the benefits *and* the risks of both previous and on-going industrial revolutions are so unequally shared. According to Oxfam, in 2020 the worlds' richest 1% people, many beneficiaries of them of 'the fourth industrial revolution', have more than twice as much wealth as the world's poorest 6.9 billion people possessed together (Oxfam, 2020).[2]

Neil Harbisson, the fourth industrial revolution, unequal access, and vulnerability to the effects of technological development—all of these phenomena point not only to the increasing entanglement between human systems and the natural world but also, more strongly, to moral questions inherent to technological development. As Mike Hulme puts it, 'because we can' is never an adequate justification for human beings, for whom the categories of wise and foolish, good and bad, right and wrong are unavoidable—even if we do not always know where to locate them' (Hulme, 2014, p. 109). Such questions are constantly at play in climate engineering. Apart from questions of feasibility (Chapter 4) and politics (Chapter 5), climate engineering always needs to answer questions of desirability—moral questions about the relationships between humans themselves and between humans and their environment.

Clearly, those relationships have changed beyond recognition since the first industrial revolution. From a world of relative constancy and stability, change and development are now fundamental aspects of the collective imagination. Nature too is no longer perceived as a stable entity. After Copernicus' decentralisation of the Earth in the Universe and Newton's deeply influential mathematisation of the physical laws, Darwin's theory of evolution and

Agassiz's theory of climatic change solidified *continuous change* as the dominant imagination of both human society and Nature. Simultaneously, the historical experience of time changed, introducing into the collective imagination the idea of 'progress' (Koselleck, 2004). This altered attitude, this vision of change, also meant that humans could start to think of *themselves* differently. The future became fundamentally different from the present, and slowly the future as a category for action started to matter—as something to act towards, not only through personal aspirations but also as a human society (Polak, 1973). Through the work of early climatologists and ecologists, such an awareness of the future became ecological as soon as it became possible to imagine 'man as a geological agent' (Sherlock, 1922). In the 20th century, multiple trends amplified the human impact on a wide range of natural systems, in unplanned, unexpected, and sometimes undesired ways. Global economic growth, for one, measured in gross domestic product (GDP), skyrocketed in the first few decades after the Second World War. Whereas 'economic growth' had remained somewhat enigmatic before the war—and was by no means a policy aim in and of itself—GDP growth soon came to represent economic and political prosperity in the public and political imagination. By the 1960s, GDP growth had become an ultimate aim of political policy (Raworth, 2017). This explosion of economic growth, magnifying human impact on planetary systems, also took place outside of the 'developed' world. Former colonies weaned themselves from their oppressors by demanding (and fighting for) independence. In doing so, they freed themselves from the artificial shackles to their economic development their colonial masters had imposed (Bonneuil and Fressoz, 2017; Ghosh, 2017). This twinned 'Great Acceleration', as it is often called, dramatically increased the impact of human societies on the planetary systems (McNeill and Engelke, 2014). By the 1960s, recognitions of human influence became commonplace through an environmental movement electrified by Rachel Carson's *Silent Spring* (1962). A series of books and theories warned of human influence on the environment—and about the fragility of the future. Paul Ehrlich's *Population Bomb* (1968) and the 1972 'The Limits of Growth' report (Meadows, 1972) solidified an imagination of the Earth as fragile and of humans as decisive actors in that fragility. Scientifically, Lynn Margulis and James Lovelock's Gaia theory warned that living organisms—and by extension human societies—might decisively influence their environmental circumstances. A post-modern environmentalism which aimed at protecting natural systems from the impact of human industrial development replaced the more romantic modernist environmentalism that had been concerned with the preservation of a pristine nature (Warde, Robin, & Sörlin, 2018). Human societies, it argued, should limit their encroachment on nature—and limit their impact on the environment as a whole.

For climate engineering, such imagined relationships between people and their environment are deeply consequential. Almost without exception, climate engineers agree that anthropogenic climate change (and related environmental concerns) is changing the relationship between humans and their environment. The increasing attention (and tacit policy acceptance) for climate engineering measures is emblematic of this change. To some, carbon capture presents a classical form of environmentalism, limiting human impact by removing pollution. To others, it is a reflection of precisely the unwillingness to rethink human relationships with nature. Solar radiation management (SRM) is even more controversial. To some, it represents a form of modernist hubris, an attempt to subjugate nature, to bend it to 'our' will. Others suggest that it, like climate engineering as a whole, might present a *new* form of environmentalism. Rather than thinking about a divide between humans and nature from which a 'retreat' would be possible, they argue, climate engineering might represent a new type of environmentalism in which the deep entanglements between humans and nature are embraced. Resembling Bruno Latour's argument (2011, 2017) that post-modern environmentalism should recognise that nature and culture are never separate, this (ecomodernist) argument asks for a deep and intimate entanglement with the nature humans are part of. Part of this entanglement might, given humanity's impact on the Earth's systems, *need* to be an active form of stewardship, they argue. Some even relish in this human ability to influence, control, and change. Others fear and loath ideas about stewardship because they fear modern industrial societies are inherently destructive. Many, such as myself, oscillate between all those intuitions—and are never quite sure where to locate them.

In this chapter, I outline these differences, thematically organised around the moral questions about human-nature relationships climate engineering brings into view. Specifically, I address how climate engineering relates to the idea of the Anthropocene, the 'geological age of the human'. Many climate engineers, especially on the American side, feel enticed by the ecomodernist concept of a 'Good Anthropocene', in which humanity—or, to be more precise, a part of humanity—assumes a conscious stewardship of the Earth. Since, of course, not everyone feels equally comfortable with such an approach, this chapter focuses on how climate engineering technologies consistently raise questions about morality. Specifically, what does it *mean*, ontologically and metaphysically, to intervene consciously in the Earth's climate? What *is* a Good Anthropocene? And what is climate engineering in such a Good Anthropocene?

The Good Anthropocene: stewards of a post-modern world

In recent years, two new signifiers have come to represent humanity's influence on the globe: the Great Acceleration and the Anthropocene, two closely linked descriptions of the human influence on the larger ecosystems. The Great Acceleration has become the scholastic term to describe the exponential intensification and expansion of human processes on the Earth after the Second World War. Unprecedented population growth and exponential economic growth are the most visible examples of these trends, but many other processes also intensified (Steffen *et al.*, 2015). Human influence on the nitrogen and phosphorus cycles now vastly exceeds natural circulation. Human displacement of sand and rock rivals that of erosion, volcanic eruptions, and rivers (McNeill and Engelke, 2014). Radioactive isotopes from nuclear explosions can be measured all over the globe. And greenhouse gas concentrations (and emissions) are higher than they have been in at least 800,000 years (Meinshausen *et al.*, 2017). Although there are discussions about whether the Great Acceleration presents a radical break with earlier trends—some argue that this acceleration began at least as early as the 19th century—the sheer volume of displacement and the size of human influence on natural phenomena have sparked intense debate. This debate is closely tied to the debate on the Anthropocene, the geological 'age of the Human', introduced as a concept in 2000 by Paul Crutzen and Eugene Stoermer, a leading limnologist, in the newspaper of the International Geosphere-Biosphere Programme (IGBP) (Crutzen and Stoermer, 2000). Crutzen had first proposed the Anthropocene at a conference in Mexico because he thought the 'Holocene' did not cover the magnitude of human influence on the Earth's system anymore. Searching further, Crutzen found that Eugene Stoermer had already been using the word 'Anthropocene' informally since the 1990s. Crutzen and Stoermer's article struck a nerve. The idea that humans were interfering with nature on geologically and climatically relevant scales resonated widely. Climate change had already become an important driver of the geopolitical debate. Over the latter half of the 20th century, nuclear meltdowns, industrial disasters, pollution, and a hole in the ozone layer had confirmed human influence on the Earth time and again. In 2002, Crutzen published a follow-up article about the 'Geology of Mankind' in Nature (Crutzen, 2002). Soon after, the stratigraphical community established the Anthropocene Working Group (AWG) to determine whether it would make sense to speak of a new geological epoch. A wider academic community of historians, Earth system scientists, economists, and many other disciplines also reacted (Trischler, 2016). Outside of academia, the term 'travelled' into literature, art, and museums, transforming the Anthropocene into a cultural phenomenon describing a wider anxiety and wonder about the change humans impose on their environments.

Interest in the Anthropocene draws from a longstanding historical interest in the changing relations between humans and their environment. As early as 1775, the French naturalist Comte de Buffon observed that 'the entire face of the Earth bears the imprint of human power' (de Buffon, 1778, p. 237). In the 19th century, successors like George P. Marsh and Antonio Stoppani also reflected on the changing relationship between humans and nature (Marsh, 1864). By the early 20th century, many had come to see humanity as a geological agent (Fischer, 1915; Guillaume, 2014; Sherlock, 1922). After the Second World War, as globalisation, space flight, and scientific developments solidified an imagination of the globe as an interconnected whole, such ideas became increasingly common—culminating in Lovelock and Margulis' Gaia theory and Crutzen's Anthropocene exclamation. As a term, the Anthropocene is not uncontroversial. To many, it falsely describes our current political moment as 'the age of the human', when the environmentally destructive impact of the human is rather connected to industrial capitalism and its vast inequity. For these critics, there is something obscene about using the term 'Anthropocene' to uniformly describe human influence on the biosphere when this disruptive influence benefits only a small portion of the world's population (Haraway, 2016; Head, 2014; Moore, 2016), fearing that it pre-empts normative debate in favour of a techno-managerial discourse (Swyngedouw and Ernstson, 2018).

A particular site for such fears is technological interventions such as climate engineering—feared to be technocratic in the extreme anyway. Like other major interventions such as nanotechnology, AI, and CRISPR-Cas9 genome editing,[3] climate engineering seems, in the words of one climate engineering researcher, to 'scramble things' in humanity's relationship with nature. As such, it is difficult to disentangle the discussion about climate engineering to fundamental concerns about the Anthropocene. Although many climate engineering researchers eschew explicit use of the term, climate engineering always raises normative and ethical questions about the human role in the larger planetary systems. Central to this debate is the question whether the *deliberate* intervention in the Earth's planetary systems is meaningfully different from the inadvertent—but quantitatively immense—changes humans have already brought to their environment. It is here that the question of climate engineering becomes meaningfully 'anthropocenic'. It is undeniable that human systems have reoriented, restructured, and destroyed many natural systems—especially since the start of the Great Acceleration—and many climate engineers struggle with the implications of those changes.

To some, climate engineering is not meaningfully different from other technological interventions to begin with. As one Keith Group researcher forcefully expressed,

> who are you kidding, really? As human beings, we survive by hacking nature and now you're objecting *because* we've altered nature? Maybe try to go back to the woods then, and live there with no tools like in a Minecraft situation.[4] See yourself there and live for a flower if you really buy that argument.
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> (Researcher 3)

David Keith himself shares a similar opinion, seeing climate engineering as a (particularly controversial) continuation of the human technological drive:

> About a million years after inventing stone cutting tools, ten thousand years after agriculture, and a century after the Wright Brothers flight, humanity's instinct for collaborative tool building has brought

> us the ability to manipulate our own genome and our planet's climate. These tools rest on deep knowledge of the natural world accumulated over centuries. This knowledge was built by the efforts of countless individuals—all filled with error and motivated by self-interest—yet each also contributing to the accumulation of understanding. We may use these powers for good or ill, but it is hard not to delight in these newfound tools as an expression of collaborative human effort to understand the natural world.
>
> (Keith, 2013, p. 173/174)

To others, the human technological drive is not an adequate (moral) explanation to justify climate engineering research—let alone to 'delight in these newfound tools'. Climate engineering is qualitatively different from climate change, because it entails *deliberate* control of planetary systems. To many, being 'very sceptical about large interventions, about large planned systems' (researcher A), such deliberate control is highly problematic. At the same time, even these sceptics concede the differences between anthropogenic climate change and some forms of deliberate climate control are starting to erode. As long as climate change could be conceived of as an inadvertent *side-effect* of industrialisation and the benefits it brought, most climate engineers think it was meaningfully distinct from deliberately causing environmental change. Increasingly, however, 'people cannot say, "Well, we didn't know", anymore. They could say that 100 years back, "We didn't know." Nowadays, that's not possible anymore' (Researcher N). The longer real climate measures stay out of view, the more climate change becomes a willed manifestation of the Anthropocene, because 'as long as we live our way of living with huge emissions of CO_2, we modify and we have modified the planet' (Researcher A). As we know what we are doing, and 'we continue to do it anyway', 'we now do it intentionally'. As such, many of them agree—albeit reluctantly—that

> we're so early in the game that it's worth exploring [SRM]. [This means] thinking about how we might develop and harness this technology, this way of interacting with nature, in a way that complements what we're already doing, but achieves those goals to a much greater degree. And whether it does so in a way that helps us live in a cleaner, safer world.
>
> (Researcher 12)

Such questions matter greatly for how amenable one is to climate engineering. Whether one views climate engineering as comparable to anthropogenic climate change—just a step further in the (sociotechnical) entanglement between humans and their environment—or as a fundamentally different, hubristic step towards 'geo-management'[5] determines how one understands the development of climate engineering.

The Good Anthropocene and climate engineering

Climate engineering, then, raises questions about how to act responsibly (and fairly) in a system so dominated now by human action. By and large, climate engineering technologies introduce questions about how human societies should interact with the larger ecosystems. Disputes about whether or not to consider climate engineering technologies are inevitably also discussions about (a) whether to accept the 'Anthropocene' as an age of human control, and therefore to accept the ever-increasing entanglement between human and natural systems,[6] and (b) what a 'good' Anthropocene ought to look like. The term 'Good Anthropocene' is a controversial one, as it is widely adopted by techno-optimists—such as the Ecomodernist manifesto that David Keith co-signed—as a call for humanity to take up the mantle of planetary stewardship.[7] According to this principle, humanity has now gained such technological prowess and such vast scientific knowledge that, given careful consideration, technoscientific stewardship of the planet should be possible (and desirable) (Crutzen and Schwägerl, 2011). In this view, responsible stewardship of the Earth ought to recognise and accept the hybridity of human and natural systems. Closely related to Bruno Latour's observations that *We Have Never Been Modern* (1993), proponents of the Good Anthropocene argue that humans are not and never have been removed from nature. According to Latour, modernity artificially 'separated' humans from nature. Post-modernity, and by extension the Anthropocene, has shattered this artificial divide, making people aware that humans and nature are always entangled. Humans *are* (part of) nature. The implications of this realisation can be wide ranging. For the ecomodernist interpretation of the Good Anthropocene, the hybridity of human and natural systems means—especially given the ever-increasing impact of human systems—that humans should act as deliberate, responsible stewards. This ecomodernist reading of the entanglement between humans and nature is controversial, also in the climate engineering communities. Many think it underestimates the complexity of natural systems, that it is too optimistic about science and technology, and presupposes a 'planetary cockpit' from which such stewardship is conducted.[8] Ecomodernism ties into strong ideological convictions about technoscientific progress and assumptions that most people will want to lead a high-consumption technological life. It also ties into, as I have shown in Chapters 4 and 5, assumptions about the *knowability* of the Earth's (climate) systems and a view of society as a collection of self-interested individuals. So, in a manner rather similar to Bruno Latour's argument about post-modern entanglements (Latour, 1993, 2011)—but drawing different conclusions about the desirability of technology[9]—ecomodernists argue that the entanglement of the human and natural world is absolute. Because it is impossible to retreat from nature, the only way to minimise the (harmful) impact of human civilisation is to embrace technology as a means to make life less energy-intensive and less resource-intensive. Resembling a long lineage of techno-optimists and technocrats, ecomodernists effectively argue that it is possible to decouple economic growth from resource intensification.[10] In short, this means that ecomodernists 'affirm one long-standing environmental ideal, that humanity must shrink its impacts on the environment to make more room for nature, while we reject another, that human societies must harmonize with nature to avoid economic and ecological collapse' (Asafu-Adjaye *et al.*, 2015, p. 6). By this they mean that while humans should reduce their impact, they should technologically intensify many of their activities, relying on science and technology to guide humanity to a sustainable stewardship.

In the German SPP program, this Good Anthropocene and ecomodernism, forcefully argued for by David Keith and associates, are eyed sceptically, viewed as modernist hubris in a new suit. Given the inevitable 'side-effects' and unintended consequences of technological interventions, most SPP researchers do not trust in an ecomodernist technological stewardship. Its ideological trust in scientific knowledge and view of societies as aggregations of self-interested individuals, appeared to many simply a way to eschew structural changes in terms of the economic and energy systems—and to avoid difficult political discussions. In a rebuke of climate modellers, particularly at the way the Keith Group seems to conduct their research, a philosopher connected to the SPP argued that 'we should not make the mistake to isolate climate engineering or solar radiation management'. Instead it is important to 'see the broader picture of nature, and of justice in the Anthropocene period', and 'some people who are just modelling and doing this portfolio… are very narrow and do not see the big picture anymore' (Researcher F). I would argue this is not exactly true. Modellers (and ecomodernists) *do* tend to worry about, sometimes even obsess over, questions of justice in the Anthropocene. They just *see* them in a manifestly different way.[11] In its techno-optimism, ecomodernism facilitates a relatively optimistic interpretation of the uncertainties of both SRM and carbon dioxide removal (CDR). It takes a larger history of ever-increasing knowledge, trust in the aptness of the blinkered models they use, and a deeply culturally embedded belief in 'science as the final frontier', to argue for the adoption of climate engineering technologies. It is also the acceptance of a positivist frame, of climate knowledge, of politics, and of economics, rather than more constructivist framings that privilege uncertainty. For many of its critics, however, ecomodernism misses the point: truly post-modern entanglement means a more *intimate*, less *instrumental* relationship with our environments (Baskin, 2015; Latour, 2011, 2017; Stubblefield, 2018)—in short, more humility in the face of the complexity and moral values of natural systems.

Humility and care in the Anthropocene

In her article 'Technologies of Humility', Sheila Jasanoff (2003) called for the development of social strategies to anticipate inherent uncertainties, inevitable 'side-effects', and the limited ability of (and justification for) science and technology to control complex systems. As the culmination of a research tradition that engages with the complexity of social and natural systems and the risks of modernist managerial visions (Funtowicz and Ravetz, 1993; Jasanoff, 1994; Scott, 1998), Jasanoff's argument calls for social technologies that privilege systematic uncertainty and humility rather than sociotechnical hubris—and that leave room for normative visions and values. Such a call for humility resonates widely in the climate engineering debate. For many SPP researchers, an appreciation of the unknowability of the climate system combines with a distrust of the human ability (and willingness) to implement climate engineering technologies fairly, safely, and reliably. This apprehension lies at the heart of their attempt to *disprove* the viability of climate engineering. Rather than using further technological interventions to engage systems that will never be fully understood, such climate engineers would prefer to *refrain* from acting technologically. By introducing ever more layers of complexity to the climate engineering debate, they hope to reintroduce a measure of humility against the techno-optimist hubris of the managerial ecomodernist idea of 'stewardship'. Instead of a 'Good Anthropocene' and its notion of active human stewardship over the global ecosphere, then, many climate engineers prefer restraint and humility in human dealings with their environment. Whereas ecomodernists such as Crutzen and Keith see the adoption of stewardship in the Anthropocene as a necessary, even exciting prospect, others are far more apprehensive about such a prospect. Duncan McLaren, a British scholar of the Anthropocene and climate engineering, has suggested that—rather than an ethics of responsibility and stewardship—scientists and policymakers should adopt an ethics of care and repair (McLaren, 2018). Originating in feminist theory (e.g. Held, 2006), the ethics of care is a widely shared interest in the environmental humanities and related academic circles. It implies that a more intimate, mutually respectful relationship of care with nature is both ethically better and more environmentally friendly than a managerial or instrumental relationship with nature. Rather than thinking of the Earth as having a fever that should be cured by a doctor ('us'), for example, by using SRM as symptom treatment, the ethics for care calls for a mutually nurturing relationship, allowing both humans and nature to flourish in symbiosis. To McLaren, however, such an ethics of care doesn't fully cover the current environmental moment. In his view, the major Anthropocenic aim should be planetary *repair*, not planetary management or stewardship. Rather than creating structures and conditions that have to be maintained, such as wildlife preservation or SRM, we should aim to repair ecosystems, restoring them to an equilibrium that does not *need* human 'stewardship'. Simply put, ecosystems should be left in a state that will allow them to function independently of human interference.[12]

The ethics of care and repair corresponds to a particular strain of climate engineering scepticism. Although most climate engineering scientists are hesitant to explicitly engage with moral questions—viewing it as outside of their scientific mandate but also as socially hazardous territory—many people are drawn to an ethics of care and repair. In many ways, discussions about the shape of a 'Good Anthropocene'—and climate engineering's role in it—are *ethical* discussions underlying conceptions of the feasibility, reliability, and desirability of SRM and CDR. Hidden by numerical forecasts, economic forecasts, and research in behavioural economics, the Good Anthropocene and convictions about climate engineering all code for opinions on *how to be in the world, both individually and societally.* For many, such considerations bring out the question if—and if so, in what form—climate intervention is morally justified. Specifically, such questions revolve around whether or not deliberate climate intervention fundamentally changes something in the relationships between humans and their environments. Because of the profundity of the changes people have made to ecosystems, the question what repair and humility would look like is complicated. Although SPP researchers tend to view repair of the climate as far preferable to the geo-management they see implied in the Good Anthropocene—as would, to be fair, many Keith Group scientists—few are able to express how they think repair should look, nor where the lines between mitigation, adaptation, and climate engineering can be drawn. In principle, repairing natural ecosystems, for example, would be a good thing, but 'if you [want to] do reforestation or renaturalisation'… 'we have changed the land surface almost completely'. In order to re-naturalise and repair, 'we would now go back to change it' again. This means it 'would be a climate engineering measure, although I would consider it as positive'. At the same time, there would be no denying that 'doing so at a large scale would be a huge shock to the climate system, to eco-systems, to biodiversity, to everything'. Evidently, 'there is no clear separation between re-naturalisation, which could be mitigation of change, and climate engineering' (Researcher A).

Such uncertainty ties into the recognition that different types of climate engineering raise different types of concerns. SRM, as an attempt to 'take control of the global mean temperature', and CDR, as an attempt to maintain Holocenic climate conditions as best as possible, raise different Anthropocenic questions. The large sociotechnical systems needed to implement negative emissions technologies (NETs) and other greenhouse gas removal at the scales required certainly present human influence at Anthropocenic scales, but for most climate engineers the major moral questions centre on SRM. In all but scale and effect, CDR is often still perceived as a rather conventional form of environmental protection: limiting human influence by *limiting human impact.* SRM, on the other hand, might be construed as an act of stewardship—maintaining the 'right' climatic conditions as best as possible while other systems remove carbon dioxide from the atmosphere. From an ecomodernist interpretation, the relative merits and dangers of climate engineering come across very differently than from a Latourian perspective on post-modern entanglements. Both the stewardship of the Good Anthropocene and the call for humility and repair—while not *necessarily* mutually exclusive often in opposition to one another—reflect a more fundamental question. What does this new age, this newly found effect on the Earth's systems—the prospect of unprecedentedly rapid climatic change, a possible sixth mass extinction in the lifetime of the Earth (Kolbert, 2014), a technosphere that displaces more nitrogen and phosphorus than the ecosphere does, and more plastics in the sea than fish—mean for the metaphysical relationship between the human and its environment? In the remainder of this chapter, I address precisely how these questions surface in the climate engineering debate—and how they are ever-present, though usually implicit.

Planetary boundaries and safe operating spaces

The relationship between humans and their environment is subject to renegotiation not only through climate change but also through other human interventions and influences. The debate over what a 'Good' Anthropocene might entail addresses precisely this immense entanglement. While most climate engineers exclusively focus their research on anthropogenic climate change, all agree that climate change is not an isolated phenomenon. In the words of David Keith, which we saw in Chapter 5, the world faces a 'range of problems', so a focus 'too monomaniacal on climate' might be harmful.[13] To treat climate change as an isolated phenomenon is to miss other threats to ecosystems around the world that human societies cause. Climate change, and by extension climate engineering, cannot be properly engaged while ignorant of these confluences. Part of the Anthropocenic question that climate engineers face is how to make sure that their research (and position) reflects such a range of highly complex problems. Some of the climate engineering technologies, particularly on the CDR side, directly engage with that question. How can researchers make sure that NETs, many of which might be highly land, water, and nitrogen/phosphorus intensive, aren't an approach to climate change that harms other ecosystems? For the CDR community of the SPP, this is an especially salient question. Most carbon capture measures, except the technologically intense direct air capture (DAC), raise difficult questions about land-use pressures and global water management. As a result, many researchers voiced their express concern about the political reliance on negative emissions scenarios, because they feared other 'key environmental dimensions of the earth system' might not be taken seriously enough—key dimensions that humans now also decisively influence.

To them, seriously reckoning with the environmental plight of our times—and the warning of the Anthropocene—should at the very least attempt 'to stabilise the earth's system as a whole, which is not only controlled by climate change but can be affected also by violations of other environmental dimensions'. SPP researchers were therefore adamant that they 'want to link this climate related discourse of terrestrial carbon dioxide removal of climate engineering into the much broader discourse about the overall status of our planet along at least the nine environmental dimensions [of the planetary boundaries framework]' which, they feel, 'provides a perspective on the complexity of the system' (Researcher I). This 'Planetary Boundaries' framework, introduced by Johan Rockström, Will Steffen, and others (Rockström *et al.*, 2009; Steffen *et al.*, 2015), describes nine distinct ecological boundaries to codify human influence on natural systems. Although the planetary boundaries concept is often criticised for its reductions in complexity, effectively obscuring regional differences and structural inequalities in both peer-reviewed literature and the popular media (Montoya, Donohue and Pimm, 2018; Tantram, 2012), it introduces complex systems thinking as an important feature of environmental politics. It also functions as an important boundary object,[14] allowing scientists to communicate across the borders of their disciplines, both to each other and to non-academics. Like the IPCC, the planetary boundaries codify and solidify a particular vision of the Earth as distinct but interrelated processes, making the translation of knowledge possible and the cross-communication easy. As a result, the planetary boundaries have become a highly prominent feature of sustainability debates, much like the 400 ppm and 2°C climate goals.[15]

Aware that reducing the complexity of human-nature relations into nine boundaries is problematic, climate engineering researchers look to these boundaries to get an indication of where the main issues of concern for global human interaction with the biosphere lie. Most climate engineers, especially in the SPP, recognise that climate change cannot be addressed in isolation—not politically, as we have seen in Chapter 5, but also not ecologically. It ties into many questions of the human relationship with nature, as well as questions of agricultural practices and resource use. Addressing climate change through climate engineering should still be 'about more sustainably exploring, exploiting, managing our planet' (Researcher I). Ecomodernist techno-optimism can be problematic, because it might privilege large-scale solutions. As such, it might overestimate the human capacity to intervene and control—while simultaneously centralising human power. Like 'with agricultural crops and water management', there is a tension between 'a big industrial solution' and 'small-scale solutions that are equally promising'. Taking a serious look at the planetary boundaries means seriously discussing the intersections between climate engineering, other (un)sustainable practices, and human-nature relationships—and seriously considering *systems change*. As one researcher put it, the 'terrestrial carbon dioxide removal discussion converges with discussions of sustainable agriculture and sustainable water use', because here too there are 'systems that could be tested and explored more' (Researcher I). Taking such a more expansive, systemic view of climate engineering introduces a new range of complexities to both SRM and CDR. It also complicates the basic premises of both, which are, respectively, to keep global average surface temperature and atmospheric carbon dioxide concentrations down.

Introducing the notion of planetary boundaries into the debate around climate engineering adds an extra layer of concern. Whereas the devilish details of climate modification, as I have referred to them in Chapter 4, are crucial in order to get climate engineering to work in the first place, the planetary boundaries introduce further concerns such as the global hydrological cycles, nitrogen and phosphorus cycles, and biodiversity. All climate engineers agree on the need for contextualisation, though not all agree on what it means. The more optimistic researchers in the Keith Group felt strongly that they and other atmospheric scientists were the right people to provide such contextualisation. They feared if *they* don't do SRM research, other academic communities, more closely related to conventional engineering, would. Such engineering communities might do research where 'the science is sound, but decontextualised'. If the atmospheric science community would pull away from this research, risks inherent in the complexity of the atmospheric system might be lost. Such engineering researchers might simply ask, 'to speak colloquially, when you hit the atmosphere with a big hammer, how does it change? They just assume that it changes by getting more reflective, it compensates for carbon dioxide'. This is problematic, because 'the atmosphere and the climate are complicated systems, and when you make a change in one part there are feedback loops that affect other parts' (Researcher 5). This rebuke of non-atmospheric climate engineering researchers is instructive, because it mirrors the concerns of SPP members about the Keith Group's research almost exactly. Introducing the notion of the planetary boundaries into the debate about climate engineering shows that even atmospheric science is decontextualised from the larger environmental concerns. This, in many ways, is the core of some of the major concerns that many of the SPP researchers as well as individuals within the Keith Group have about hubristic or simplistic climate engineering science. To them, climate engineering can never be contextualised enough—and as such always requires too narrow a vision to be made to work. The conversation around capturing carbon, for example, continually zooms in and out, trying to rhyme local concerns and ecosystem imbalance with planetary systems thinking and average global temperatures. Most of its technologies—such as ocean iron fertilisation, reforestation/afforestation, and BECCS—interact with important ecological systems. Where 'SRM is more natural to the atmospheric scientists', 'CDR is more the stronghold of the terrestrial or ocean people' (Researcher E). Because the planetary boundaries are predominantly the purview of Earth system sciences rather than atmospheric scientists, the planetary boundaries play a larger role in the CDR debate. Especially now that negative emissions have made their way into the policy envelope for climate change, most SPP CDR researchers feel strongly that the effects of large-scale carbon capture should be contextualised according to its interactions with other key environmental dimensions. Future research should, to many of them, be 'situated in an even larger context', asking how 'any climate engineering measure would affect the earth system as a whole and not simply the climate system' (Researcher I). Any future climate engineering research effort should include an attempt to assess the Earth's systems as one integrated whole, not viewing climate in isolation but rather as a manifestation of a series of interactions with the larger whole of the ecosystem.

Doing climate engineering research in the Anthropocene always raises questions about whether decontextualizing the climate from wider ecological concerns and moral questions ought to be a prohibitive concern for the development and possible employment of climate engineering measures. Those more sceptical about the potential for human society to fully understand and predict the complex systems of nature insist on embedding ever more research concerns into models, research questions, and disciplinary outlooks. Sceptical SPP researchers insist that 'a lot of modelling on climate engineering has been done in global models' in which 'the key processes are not very well represented' (Researcher E), feeling that even *atmospheric* contextualisation is still lacking. As a result, sceptical climate engineers insist that 'it has become very obvious how difficult it is to work with climate models'. It is unclear how reliable they are in predicting the effects of SRM, and as such it is critical 'to try to find criteria for assessing the reliability of models involved' (Researcher O). They are also more willing to accept criticism on the blind spots of current methodologies. For the Keith Group, and related techno-optimist researchers, there is also a need to contextualise climate engineering research, but the shape of this need depends on the particular constructive aim of the research. SRM, of course, is a particularly singular approach to climate change. The Keith Group, where most believe the comparison between a climate changed world and an SRM world inherently worthwhile, tends to present climate change and SRM pretty much in isolation from other environmental concerns—except precipitation, as it is included in general circulation models (GCMs). Precisely what makes SRM attractive is its perceived simplicity. While stratospheric sulphur veils or brightening marine clouds are technical and scientific challenges to be sure, the basic premise is relatively straightforward. One of the major drawbacks of SRM, as mere symptom treatment for climate change, is also one of its major strengths. Playing solely on global surface temperatures, SRM technologies can be understood explicitly and almost exclusively in relationship to climate change. As a result, SRM discussions are tightly focused on the climatic (and geopolitical) effects of possible interventions. Asking difficult questions about complex interactions in other systems is often directly less relevant for SRM as these technologies claim climatic specificity. Looking at other boundaries might even broaden the scientific view to such an extent that it would make development-directed questions about SRM almost unanswerable.[16]

This need for contextualisation of the effects and considerations of climate engineering effects *beyond* its direct effects and aims—beyond climate change—reflects a growing awareness of both the complexity of the biosphere and the multiplicity of human-nature interactions. No longer can environmental concerns be addressed in isolation—if they ever could—as they immediately raise moral questions about a spectrum of human-nature relations, and almost inevitably raise metaphysical questions. Specifically, it brings into even sharper focus what it would mean for human-nature relationships to *deliberately* alter the climate.

The metaphysical elevation of the human

The question whether or not climate engineering is similar to human interventions of the past is still an open question, and it influences whether or not one feels comfortable doing climate engineering research. Seeing inadvertent climate change and deliberate intervention as fundamentally different increases the hesitance about whether or not to engage in climate engineering, because it alters issues of liability, responsibility, and morality. Almost without exception, such opinions also tie into visions of feasibility and governability of climate engineering. For those opposing climate engineering, particularly SRM, it is therefore important to retain a moral (and political) distinction between climate engineering and anthropogenic climate change. Typically, there are two major reasons to make a moral distinction. The first is that climate engineering deliberately adds a 'thermostat', which has severe political implications. The second is that it *adds* another layer of intervention, not as a side effect but as a willed effect. As one researcher expressed, 'mitigation that I'm doing now will affect the future but this future is also affected by past emissions'. Climate engineering is different, because 'climate engineering you can argue has not happened in the past' (Researcher N). Clearly,

> once you've decided to take control of the global mean temperature in whatever manner, that barrier is no longer respected. I don't know to what way you can then bring it back. I think you're either deliberately controlling the climate or you're not.
>
> (Researcher 4)

Climate engineers grappling with questions surrounding the 'age of the human', arguing for humility or stewardship, always have to grapple with ontological and metaphysical questions about the relationship between humans and their environment. Many view the deliberate intervention in the Earth's climatic systems as morally abhorrent, because it feels like 'playing God'. Religious and spiritual groups often mean this quite literally, asserting that humans have no right to intervene with Nature on such a scale (e.g. Chan, 2018). For most climate engineering researchers, however, the fear of 'playing God' is proverbial. It alludes to the hubris of scientists and politicians thinking that they can influence and control the planetary environment, to uncertain effects (Hartman, 2017). Often, the distinction between the literal and proverbial interpretation of this argument is not entirely clear. Many climate engineers intuitively feel that there are certain moral, ontological, and metaphysical limits to intervening in nature—although they often attempt to capture those moral convictions in scientific terms. Some are more explicit, admitting they struggle a lot because 'you certainly don't want to play God'. An intuition rather than a 'rational argument', this means they 'feel like messing with the natural system is crazy. It feels as something I shouldn't really do. It is more metaphysical. I can't describe it. It's like a feeling that the fact you would control the world feels wrong' (Researcher 9). At the same time, here too this intuition raises questions about whether climate engineering is meaningfully different from climate change, because

> whether or not we [influence the climate] with our eyes closed or our eyes opened, I don't think they're different… We released a lot of CO_2, and it's causing problems. Saying now, "Oh, I can't use carbon capture to absorb all that CO_2, 'that's playing God", I think that's hypocritical.

Needless to say, this is not a question exclusive to the climate engineering debate. Religious arguments against playing God have also entered public debates around biomedicine and genetic modification of organisms—especially the modification of humans and other higher animals—as well as the debates surrounding nanotechnologies, artificial intelligence, and space exploration. Invariably, such controversies revolve around moral conviction about what the prerogative of human action is and, importantly, what *isn't*. In recent years, this question has become ever more pressing, as human technology becomes ever more invasive. Human collective power, some feel, is becoming god*like*. Books such as *Homo Deus* (2016) by the Israeli historian Yuval Noah Harari and the *God Species* (2011) by the ecomodernist science writer Mark Lynas stipulate that humans now hold powers through science and technologies that rivals those of the Gods of old. Some, such as Mark Lynas and David Keith, are (mostly) excited about this prospect. Others, such as Yuval Harari, are (mostly) apprehensive. Moral questions about which technological interventions are ethical and which aren't are closely tied to questions about what a 'Good Anthropocene' would look like. They are also deeply political questions (Jasanoff, 2016). As Yuval Harari (2016) notes, the godlike capacity of the 21st-century human is not only uncertain but also not available to everyone. Promises of immortality, artificial intelligence, and unlimited wealth, for example, seem restricted to those born in the right place at the right time—and certainly don't benefit everyone equally. Like the Good Anthropocene, the intuition about 'playing God' raises the question about to whom the power of influence is available, how reliable it will be, and who the technologies will benefit. If one speaks about the God species, a *Homo Deus*, then who gets to be God and who its subjects?

Because the question what types of technologies are morally acceptable as part of human-nature relationships is importantly cultural, attitudes differ according to locations, research cultures, and wider civic epistemologies. As studies of science and technology have shown, different countries have *very* different cultures around the acceptance of new and tendentious technologies (e.g. Felt, 2015; Jasanoff, 2007; Sleeboom-Faulkner and Hwang, 2012). Even between superficially similar cultures such as Germany and the United States, there are large differences in the uptake of controversial technologies. Such concerns also play in nanotechnology and other technological debates (Peters, 2007; Vandermoere *et al.*, 2010). Genetic modification, for example, is eyed much less sceptically in South Korea and China than it is in Europe (Frewer *et al.*, 2013), where objections are often levelled around the theme of playing God and the felt need for restraint. More often than not, the specific fear of playing God is a reference to a monotheistic construct, speaking to the largely Christian traditions in Europe and the United States,[17] leading to a particular form of restraint. In the climate engineering debate, mostly dominated by Western scientists, this takes a peculiar form. Although both German and American researcher expressed their apprehension about playing God, this took slightly different forms. Playing God in the terminology of the German SPP researchers was typically a more proverbial expression of a reluctance to intervene in nature. With Christian theology still playing a much larger role in their society, many of the American researchers expressed a more literal fear of playing God. In the United States, climate engineering research often solicits serious theologically laden backlash. Several members of the group received death threats filled with biblical references because climate engineering is perceived by some as an affront to God. As such, the literal questions what powers humans should wield and which should be left to God are much more prominent (to some).

The question of playing God touches directly on deeply felt visions of nature and the environment, as well as the role of the human in that system. To some researchers, even in the SPP, this is precisely a reason for climate engineering research, as

> one reason why I find climate engineering research so interesting is that we should inform ourselves about what is possible and what might be good for humankind as free as possible from ideologies of 'Don't intervene with nature at all'.
>
> (Researcher N)

At the same time, others always argued for some restraint in relationship to nature, sometimes implicitly relating to Christian theology. For many of SPP members, climate engineering is troubling, because 'there's the question of whether we should, of whether there should be something left that is not controlled'. Their conviction, 'not anything based on an actual reason, or good numbers, or figures', is that 'some things in life have to be accepted'. Part of the human experience is, and should be, in their view, 'having to deal with things that come' and 'having someone, or even a massive amount of people, control [the weather and climate], takes away something' from that experience. This conviction, that it is not the place of humans to control everything, underlies the unease many climate engineers (and others) have about imaginations about geo-management and the Good Anthropocene. Accepting that not only is it impossible for humans to control complex natural systems, those arguing for humility not only feel that climate engineering might be politically or technologically unfeasible but also feel that it is *inherently* problematic. It is undesirable on a moral level. Ethically, even metaphysically, climate engineering does not fit the kind of society we should want. Clearly, ecomodernists who are calling for a Good Anthropocene and a responsible stewardship tend to give less weight to this consideration.

The human and the biosphere

The intuition that some things are, or at least should be, out of control of human societies and individuals also reflects the intuition that, if they are not careful, humans might be their own undoing. A favourite trope of science-fiction and post-apocalyptic narratives, a growing academic field addresses the risk that human technological systems, warfare, or environmental destruction leads to civilisational collapse or even human extinction. This fundamental risk, captured by Nick Bostrom, director of the *Future of Humanity Institute* at Oxford University, as 'existential risk' (Bostrom, 2003, 2013; Bostrom and Ćirković, 2008), grows as the human technosphere[18] intensifies its hold on natural system. To Bostrom and his colleagues, it is of crucial importance to further investigate existential risks (Matheny, 2007). In his PhD thesis at Rutger's University—prominently featured on Bostrom's website—Nick Beckstead (2013) argues that 'from a global perspective, what matters most (in expectation) is that we do what is best (in expectation) for the general trajectory along which our descendants develop over the coming millions, billions, and trillions of years' (Beckstead, 2013, p. ii). As human influence on the environment grows, the salience of existential risk literature—and its moral conviction that preventing human extinction ought to be the supreme moral aim of humanity—also does. According to Lord Martin Rees, the 60th president of the Royal Society (2005–2010), 'we should at least start figuring out what [existential risks including climate-induced risks] can be left in the sci-fi bin (for now) and what has moved beyond the imaginary' (Rees, 2013, p. 1123). Specifically, we should, Rees insists, address human-made risks, because humanity has managed to survive 'natural' existential risks for millions of years, while human-induced existential risks are historically unprecedented. Morally and ethically anthropocentric, the existential risk literature ascribes to human civilisation and existence the highest moral value. As such, maintaining (the flourishing) of human life should be the primary aim of scientific research, technological development, and political choices. At the other end of the spectrum, there are increasingly prominent voices arguing *against* such anthropocentrism (Morton, 2018). Humans should not, in this view, be the central moral concern—or at least not occupy such an outsized presence compared to non-human existence. Risks to human existence and societies are important to be sure, but so are threats to ecosystems. Human existence cannot be elevated above other aspects of nature—and as such, human *stewardship* in the Anthropocene is dangerously anthropocentric. At its most extreme, views of deep ecology argue that human extinction, or at least civilisational collapse, might on the whole not be all bad.[19] Such sentiments tie into a growing 'Dark Ecology' movement that seriously questions the relationship between humanity and its environment—and feels that a complete de-modernisation might be preferable to an ecomodernist Good Anthropocene.

For climate engineering, both these views are highly relevant. Climate engineers are by no means immune to growing concerns about human extinction, nor to the thought that this may, perhaps, not be a bad thing. To many of the more techno-optimist researchers, climate engineering research presents a safeguard against the existential risks climate change might pose. Others view climate engineering—the prospect of SRM or delayed mitigation due to expectations about CDR in particular—as an existential risk in its own right. Yet others feel drawn to the arguments of dark ecology, hesitating about climate engineering *because* they seriously question modernisation and human-nature relationships. Researchers on both sides of the Atlantic expressed to me that they sometimes felt that human extinction might on the whole not be all bad. By and large, however, most people consider climate engineering seriously because they fear that, in the long run, anthropogenic climate change might very well lead to existential risks. As such, it is always better to be prepared. In this part, finally, I want to draw out some tensions, raising questions about the long-term and existential risk in relation to climate change and climate engineering. Much here is speculative, resulting from conversations and reflections of people ruminating about the meaning of climate engineering. But it is never a bad thing to raise more questions than one can answer—provided they are the right questions.

To a large extent, existential risk is the discursive justification for climate engineering research. SRM research in particular is often condoned, specifically by the more reluctant climate engineers, for a 'case of emergency' situation—to avoid catastrophe. *Eventually*, many feel, some form of climate control is unavoidable. As a PhD student put it, 'the reality is that we are living in this kind of sweet spot where we've adapted and become comfortable at a certain temperature range'. This sweet spot, however, is not a given, because 'there have been so many different climates in Earth's history, much warmer, much colder, snow, water, crazy stuff'. If humans want to continue their civilisations on a longer term, 'I always feel like it is inevitable that we will have to do some sort of weather or temperature control'. Without anthropogenic climate change, that 'might be hundreds and thousands of years into the future' but 'if it's not climate change, the Earth's climate will eventually drastically shift', possibly 'into the cyclical ice ages in the history of the Earth'. So, 'if we're here long enough, we either need to be prepared to adapt—and I don't know whether that's feasible for such drastic changes—or have more control over the system' (Researcher 9). Although anthropogenic climate change has moved up that timeline, climate control might always have been inevitable for the prevention of human extinction—at least in the long term. Moreover, 'it is not the first time that one species is changing the environment' (Researcher P).[20]

Most of the time, climate engineers do not talk about these issues extensively. Neither the SPP nor the Keith Group discusses metaphysics as part of their research. The work does not lend itself to deep reflection on these issues. The researchers grappling most with these concerns were often the ones most uncomfortable with climate engineering research—often intending to leave climate engineering research at the end of the current contracts. The controversy of and their discomfort with climate engineering exacerbated the uncertainty and pressures of academic life to such an extent that they were not willing to continue the research. At the same time, such considerations do influence research design. Considerations of a world in which humans no longer exist make it possible for climate engineers to view the effects of human societies with a certain detachment. Most climate engineers are quick to stress that anthropogenic climate change is first and foremost a *human* problem, because 'should chaos strike and humankind be wiped out, the Earth will be fine' (Researcher 9). Of course, climate change would also lead to a large number of animal and plant extinctions. Individual species will suffer due to human-induced climate change. Whole ecosystems might collapse and the world might become scarcely recognisable. But generally, 'the Earth will be fine'. It and its ever-changing biosphere have existed for billions of years. It is humanity itself (and its contemporary species) that has evolved to exist specifically in this climatic era. Life has flourished in fundamentally different climates. Those most optimistic about the potential of climate engineering—the ecomodernists who see climate engineering as a continuation of the human inclination to tinker technologically—are most conflicted about this realisation. Existential risk, to them, should be a central political and technological concern. To them, climate engineering, is precisely that: taking existential risk seriously. Those more hesitant about climate engineering, who think that engineering the climate is a major break with previous technological interventions, typically agree that existential risk is a serious worry, but question whether climate engineering research doesn't simply exacerbate that risk—risking catastrophic consequences of SRM implementation, political tensions and war over climate control, or even simply by working to delay conventional mitigation. Some of them even ruminate about whether humans have become such a disruptive part of the ecosphere that a more expansive moral framework, eschewing human exceptionalism, might even view human extinction positively. In such a view, engineering the climate for human optima is *deeply* problematic.[21]

Such ruminations by climate engineers tie into a larger debate brought on by the Anthropocene, one that no one feels is satisfactorily dealt with. What is the rightful place of human societies in the biosphere? Can it ever be acceptable to act as a managerial steward of the Earth as a whole? Who would even be in control managerially? Are we a 'we' as humans? And is that 'we' still part of nature or its manager, lodged above the rest of the biosphere? The ecomodernist Good Anthropocene and the opposing call for humility both envision guidelines for action. They also call for reflection not just on the role but also on the moral position of the human. Climate engineers do not often talk about these questions openly, at least not in scientific debate. Instead, they imagine the long future of the human on the basis of models and projections, often using it as a quantitative proxy for normative and moral debates.

Conclusion: the world we want to live in

In this chapter, I aimed to broaden the grounds upon which we decide whether SRM and CDR will be desirable, reliable, or governable by deepening questions about what the right measures of reliability, governability, and desirability ought to be. I did so by showing a range of moral convictions that hide behind scientific positions on climate engineering. Whereas in previous chapters the determining factors were physical characteristics of the climate and the right way to look at human society, this chapter is more fundamental. What is a human allowed to do? Can we speak of the human species in its totality or is this age of the human that we speak of merely the age of some humans, of some human system? Normative questions about justice and metaphysics can never be ignored. In fact, they are ever-present. Morality might not openly show up in scientific publications or conversations, but it always underlies scientific research questions. It also informs all positions on climate engineering. Advocates of SRM implicitly argue that there is a moral obligation to seriously consider SRM, for many reasons. It could help developing countries develop economically. It could stave off climate disaster. It could protect the vulnerable—and rejecting it out of hand is a privileged reaction from the comfortable safety of Western economies. David Keith's advocacy for using the combination of CDR and SRM to reduce 'peak' warming, for example, ties into a moral conviction about a managerial form of climate repair. It also ties into a particular interpretation of modernist progress in which developing countries have a *right* to develop as much as OECD countries. Others view climate engineering, and SRM in particular, as supremely hubristic. To them, climate engineering fundamentally clashes with moral convictions about the human conditions and human-nature relationships. Climate engineering will *always* be, first and foremost, a political and moral discussion. Science is important to *inform* that discussion, but it should not be allowed to monopolise it. Fundamentally, climate engineering always raises one simple but deeply political question: in what world do we want to live and how do we shape such a world?

Climate engineers often defend their controversial research by expressly demarcating their expertise from their normative and moral convictions. If scientists only provide their model outcomes or their assessments of possible economic and political futures, rather than engaging with questions that intimately connect to subjectivity and opinion, they pre-empt discussions about integrity, applicability, and values. Although the success of this demarcation is debatable, it certainly is a problematic approach to a proposed set of technologies that are both highly controversial and highly consequential. Too often, ethical and normative discussion remains the prerogative of speculative observers at the edges of the climate engineering debate. It doesn't fit within the models, and it isn't part of typical, rational scientific conversation. It is too esoteric, too impractical, of no immediate use and thus of no concern to the scientific debate. It is the home turf of the philosopher and the theologian, the literary scholar and the anthropologist, not that of the climate modeller or the Earth system scientist, the economist or the political scientist. Scientists gain much of their authority from a methodical application and perceived rationality. Most climate engineers see deviations from this 'rationality' as unscientific.

But climate engineering will always raise difficult questions that science can't answer. Decisions made, research done, and technologies developed—none of these things will answer the fundamental questions raised by the intensifying disruption caused by the increasing entanglement between humans and nature. It isn't just climate engineering that raises such questions. Climate engineering is one part of a larger cultural discussion about the rightful place of science and technology—and the rightful place of the human in the larger biosphere. Other technological developments such as nanotechnology, artificial intelligence, and genetic biology, are also normative and political developments as much as they are technological and scientific. With all of them, one needs to question what they bring to society and what their effects are. Artificial intelligence and data-driven decision-making, for example, implicitly embed normative assumptions about race and class, reifying and re-inscribing them in the decisions they facilitate (Eubanks, 2017; Noble, 2018). Historically, some technologies, such as coal-fired energy, have proven to be great equalisers, while others, such as oil, have systemically strengthened existing power structures (Mitchell, 2011). Yet others, such as nuclear energy and atomic bombs, have needed a military industrial complex and securitisation (Winner, 1980). Climate engineering research is already having important political effects. *Implementation* will have even more.

These concerns are not equal for all climate engineering technologies, and as we go forward it will be crucially important to discuss technologies *on their own merits*—technologically, politically, scientifically, and ethically. For many people, ethical questions concerning negative emissions are questions of political economy and justice. Because many see it as a form of 'traditional' environmentalism, limiting the human impact on the biosphere, or (for techno-optimists) as an extension of mitigation, CDR concerns are mostly about the question whether counting on negative emissions can ever be just. Isn't it unfair to expect future generations to mitigate current emissions[22]? And, perhaps even more pressingly, won't CDR exacerbate already existing inequalities? For SRM, such justice questions about the political economy also play a role, but the moral debate is broader too. Once 'you cross the threshold' of actively trying to control the Earth's thermostat, there may be no going back. It may fundamentally alter human-nature relationships. On the other hand, this may also be a 'fear of the new': IVF, nanotechnology, and genetic modification all also were regarded as hubristic attempts to 'play God' that have now become normalised to some degree.

Climate engineers always project the world they want to live in into their views on climate engineering—as rightly they should, as long as they are open about it. When Gernot Wagner presents SAI as something that could be useful against the 'fat tail of climate change', when David Keith teaches his students or a wider audience that SAI could be a tool to 'shave the peak of global warming', they implicitly present climate engineering research as a moral necessity that can safeguard further economic and technological development. When researchers say they do not want to 'play God', that deliberately trying to control climate 'crosses a threshold', or say that 'we should not make the mistake to isolate climate engineering from the broader picture of justice in the Anthropocene', they use metaphors and doubts to express deeper moral qualms about climate engineering. To do research effectively, climate engineering simply cannot constantly foreground existential metaphysical questions. It seems that the longer people work on climate engineering, the more normalised the thought becomes to them. While their opinion about the desirability of climate engineering doesn't necessarily change, once the initial shock of the prospect of a designer climate dissipates climate engineering, *research* becomes business as usual. To do research, scientists focus on their field of expertise, pushing other questions out as much as possible. This is understandable. But that cannot be the societal discourse or imaginary around climate engineering. Unthinkingly accepting certain structures and dreams (like economic growth or climate control) doesn't mean that the fundamental questions disappear. In its essence, climate engineering is a set of post-modern technologies aimed to 'solve' the side effects of industrial modernity. There can be no one solution, no one uncontested truth, and no complete consensus on it, because it addresses fundamental normative questions about the world we want to live in.

Notes

1 With the price of entry being at least 71,000 dollars (Sorkin, 2011), the annual Davos meeting presents itself as an intellectual meeting space for 'world leaders' guiding the future of the world.
2 Such metrics for 'wealth' are not unproblematic. The wealth of such billionaires typically does not exist in 'real' terms, but is rather an imaginary valuation of their stakes and shares in companies. Nonetheless, these figures paint a damning picture of the stark contrast between *ascribed* wealth and *real* poverty—and *do* represent very real and stark power imbalances.
3 Highly specific DNA targeting using bacterial enzyme systems in order to achieve specific changes to organisms (Doudna and Charpentier, 2014).
4 Minecraft is a popular video game in the 'sandbox survival' genre, in which the player starts out with a character that barely has any tools or resources at their disposal. Through clever resource collection and toolmaking, this character can eventually build houses, parks, and even cities.
5 One of the imaginaries around climate engineering that Jeremy Baskin identifies (Baskin, 2019).
6 And deliberate human influence *on* those natural systems.
7 Steffen, Crutzen, and McNeill (2007), three of the most influential Anthropocene advocates, have previously argued that the Anthropocene offers three options: business as usual, which will surely lead to catastrophe; mitigation, which uses the planetary boundaries to reduce the human impact on ecosystems; and geoengineering, in which humanity compensates for its impact by using technology to become stewards of the planetary systems. As Stubblefield (2018) and Baskin (2015) note, however, these options still retain a rather instrumental divide between humans (or 'Man') and the nature around, elevating the human above nature.
8 The argument against assuming a planetary cockpit typically revolves around fears of technocracy, undemocratic decision-making, and global economic and power imbalances (Hajer *et al.*, 2015).

9 Latour himself perceives and presents climate engineering, especially SRM, as a supreme form of technological hubris—and certainly not as a meaningful reckoning with the hybridity of human and natural systems (Latour, 2017).

10 Many of the promises and convictions of the ecomodernists closely resemble earlier technocratic movements, especially in seeing the providence of science and technology as the future of humanity. See Akin (1977) for a more in-depth history of early 20th-century technocratic movements for a comparison.

11 Outright rejection of climate engineering, for example, to them can seem *deeply* unjust, because many of the people that will suffer most from this rejection will be the poor and vulnerable in developing states.

12 One should not mistake this argument for an argument in favour of pristine nature, untouched by human systems. One of the fundamental realisations of the Anthropocene is that such nature doesn't exist anymore (Crutzen and Schwägerl, 2011; Latour, 2011). Climate change, chemical and radio-active pollution, as well as other developments such as ozone layer depletion have guaranteed that human influence will be measurable and deep at all surface areas of the Earth—though arguably perhaps not everywhere underneath the lithosphere. The argument for repair does, however, call for making sure that ecosystems, and especially the larger global biosphere, do not become dependent on human management.

13 To Keith, this also means that we shouldn't forget that *environmental* problems aren't the only problems the world faces. There also still are poverty and inequality, political struggles, and many others concerns that desire political and societal attention.

14 Boundary objects are sociological entities that are taken up in different communities, both scientific and otherwise, that are flexible enough to be adapted and interpreted according to the needs of those communities while simultaneously maintaining 'a common identity across sites' (Star and Griesemer, 1989, p. 393).

15 Like these goals, which we saw more extensively in Chapter 4, the planetary boundaries facilitate a useful discursive approximation of the complexity of the natural systems. In doing so, they make it possible to address specific ecological concerns much more effectively through the selective reduction in complexity that they allow for.

16 I will say more about this need for a narrowly focused vision in Chapter 7.

17 As well as predominantly Islamic or Judaic traditions in other places.

18 In the post-Great Acceleration world, this infrastructural counterpart to the biosphere identified by Peter Haff (2013) now amounts to 30 *trillion* tons of material, rivalling the non-human displacement of material across the Earth (Zalasiewicz *et al.*, 2017). According to Haff, the technosphere now has become so vast that it has become self-driving. Mirroring older fears of Lewis Mumford (1934) and Martin Heidegger (1977), Haff's provocation insists that technology may have taken on a life of its own.

19 This view too has a long history in popular culture. The 1995 film *Twelve Monkeys*, for example, featured a terrorist activist group seeking complete demodernisation, even human extinction. In major hits such as *The Matrix* and children's animation films such as *Wall-E*, humans cause their own demise.

20 As Andrew Watson and Tim Lenton (2011) chronicle, there have been multiple occasions on which biospheric influence on the Earth's climate was so great that it manifestly changed the planetary environment as a whole.

21 Of course, climate engineering need not just be to maintain *human* optima. Many more optimistic climate engineers propose the use of SRM to *slow the rate of change* not only to give human societies time to adapt but also specifically to give ecosystems more time to adapt.

22 David Keith and Oliver Morton repeatedly brought up the following response to this question, however—one that I am personally quite partial to: as a society, we

always put obligations on our future generations, simply by embedding certain structures, infrastructures, and cultural traditions. Why are negative emissions fundamentally different than, say, intensive agriculture and industrial systems that also have to be maintained indefinitely? I add this is not to argue one way or the other—because, like with many of these issues I am unsure where I lean personally—but to stress that this question is *much* more complex than it first appears.

References

Akin, W. E. (1977) *Technocracy and the American Dream: The Technocrat Movement, 1900–1941*. Berkeley: University of California Press.

Asafu-Adjaye, J. *et al.* (2015) *An Ecomodernist Manifesto*. Oakland, CA: Breakthrough Institute.

Baskin, J. (2015) 'Paradigm Dressed as Epoch: The Ideology of the Anthropocene', *Environmental Values*, 24(1), pp. 9–29. doi: 10.3197/096327115X14183182353746.

Baskin, J. (2019) *Geoengineering, the Anthropocene and the End of Nature*. Cham, Switzerland: Springer International Publishing. doi: 10.1007/978-3-030–17359-3.

Beckstead, N. (2013) *On the Overwhelming Importance of Shaping the Far Future*. Rutgers University. Available at: https://rucore.libraries.rutgers.edu/rutgers-lib/40469/PDF/1/play/ (Accessed: 9 August 2020).

Bonneuil, C. and Fressoz, J. B. (2017) *The Shock of the Anthropocene: The Earth, History and Us*. Paperback edition. Translated by D. Fernbach. London, UK; New York, NY: Verso.

Bostrom, N. (2003) 'Are You Living in a Computer Simulation?', *The Philosophical Quarterly*, 53(211), pp. 243–255. doi: 10.1111/1467–9213.00309.

Bostrom, N. (2013) 'Existential Risk Prevention as Global Priority: Existential Risk Prevention as Global Priority', *Global Policy*, 4(1), pp. 15–31. doi: 10.1111/1758–5899.12002.

Bostrom, N. and Ćirković, M. M. (eds) (2008) *Global Catastrophic Risks*. Repr. Oxford, UK: Oxford University Press.

de Buffon, G. L. L. (1778) *Histoire naturelle générale et particuliére, Supplement 5: Des époques de la nature*. Paris, France: Imprimerie royale.

Carson, R. (1962) *Silent Spring*. Boston, MA: Houghton Mifflin.

Chan, R. (2018) 'Controversial Climate Fix Poses New Question: Is Geoengineering Playing God?', *National Catholic Reporter*, 16 July. Available at: https://religionnews.com/2018/07/16/controversial-climate-fix-begs-new-question-is-geoengineering-playing-god/ (Accessed: 9 August 2020).

Crutzen, P. J. (2002) 'Geology of Mankind', *Nature*, 415(6867), pp. 23–23. doi: 10.1038/415023a.

Crutzen, P. J. and Schwägerl, C. (2011) *Living in the Anthropocene: Towards a New Global Ethos*, *Yale Environment 360*. Available at: https://e360.yale.edu/features/living_in_the_anthropocene_toward_a_new_global_ethos (Accessed: 8 Feburary 2021)

Crutzen, P. J. and Stoermer, E. (2000) 'The Anthropocene', *Global Change Newsletter*, 41, pp. 17–18.

Doudna, J. A. and Charpentier, E. (2014) 'The New Frontier of Genome Engineering with CRISPR-Cas9', *Science*, 346(6213), p. 1258096. doi: 10.1126/science.1258096.

Ehrlich, P. R. (1968) *The Population Bomb*. Cutchogue, NY: Buccaneer Books.

Eubanks, V. (2017) *Automating Inequality: How High-tech Tools Profile, Police, and Punish the Poor*. First Edition. New York, NY: St. Martin's Press.

Felt, U. (2015) 'Sociotechnical Imaginaries and the Formation of Austria's Technopolitical Identity', in Jasanoff, S. and Kim, S. H. (eds) *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*. University of Chicago Press. doi: 10.7208/chicago/9780226276663.001.0001.

Fischer, E. (1915) 'Der Mensch als geologischer Faktor', *Zeitschrift der Deutschen Geologischen Gesellschaft Band*, 67.

Frewer, L. J. *et al.* (2013) 'Public Perceptions of Agri-food Applications of Genetic Modification – A Systematic Review and Meta-analysis', *Trends in Food Science & Technology*, 30(2), pp. 142–152. doi: 10.1016/j.tifs.2013.01.003.

Funtowicz, S. O. and Ravetz, J. R. (1993) 'Science for the Post-normal Age', *Futures*, 25(7), pp. 739–755. doi: 10.1016/0016–3287(93)90022-L.

Ghosh, A. (2017) *The Great Derangement: Climate Change and the Unthinkable*. Paperback edition. Chicago, IL; London, UK: The University of Chicago Press (The Randy L. and Melvin R. Berlin Family Lectures).

Guillaume, B. (2014) 'Vernadsky's Philosophical Legacy: A Perspective from the Anthropocene', *The Anthropocene Review*, 1(2), pp. 137–146. doi: 10.1177/2053019614530874.

Haff, P. K. (2013) 'Technology as a Geological Phenomenon: Implications for Human Well-being', in Waters, C. N. *et al.* (eds) *A Stratigraphical Basis for the Anthropocene*. London, UK: Geological Society, Special Publications, 395, pp. 301–309.

Hajer, M. *et al.* (2015) 'Beyond Cockpit-ism: Four Insights to Enhance the Transformative Potential of the Sustainable Development Goals', *Sustainability*, 7(2), pp. 1651–1660. doi: 10.3390/su7021651.

Harari, Y. N. (2016) *Homo Deus: A Brief History of Tomorrow*. London, UK: Harvill Secker (Vintage Popular Science).

Haraway, D. J. (2016) *Staying with the Trouble: Making Kin in the Chthulucene*. Durham, NC: Duke University Press (Experimental Futures: Technological Lives, Scientific Arts, Anthropological Voices).

Hartman, L. M. (2017) 'Climate Engineering and the Playing God Critique', *Ethics & International Affairs*, 31(3), pp. 313–333. doi: 10.1017/S0892679417000223.

Head, L. (2014) 'Contingencies of the Anthropocene: Lessons from the "Neolithic"', *The Anthropocene Review*, 1(2), pp. 113–125. doi: 10.1177/2053019614529745.

Heidegger, M. (1977) *The Question Concerning Technology, and Other Essays*. New York, NY: Garland Publishing.

Held, V. (2006) *The Ethics of Care: Personal, Political, and Global*. Oxford, UK; New York, NY: Oxford University Press.

Hulme, M. (2014) *Can Science Fix Climate Change? A Case against Climate Engineering*. Cambridge, UK: Polity Press (New Human Frontiers Series).

Jasanoff, S. (1994) *The Fifth Branch: Science Advisers as Policymakers*. 2. print. Cambridge, MA: Harvard University Press [u.a.].

Jasanoff, S. (2003) 'Technologies of Humility', *Minerva*, 41(3), pp. 223–244. doi: 10.1023/A:1025557512320.

Jasanoff, S. (2007) *Designs on Nature: Science and Democracy in Europe and the United States*. 5. print., 1. pbk. print. Princeton, NJ: Princeton University Press.

Jasanoff, S. (2016) *The Ethics of Invention: Technology and the Human Future*. First edition. New York, NY: W.W. Norton & Company (The Norton Global Ethics Series).

Kaplan, S. (2016) 'By 2050, There Will be More Plastic Than Fish in the World's Oceans, Study Says', *The Washington Post*, 20 January. Available at: https://www.washingtonpost.com/news/morning-mix/wp/2016/01/20/

by-2050-there-will-be-more-plastic-than-fish-in-the-worlds-oceans-study-says/?utm_term=.8974dfc4945b (Accessed: 9 August 2020).

Keith, D. W. (2013) *A Case for Climate Engineering*. Cambridge, MA: The MIT Press (Boston Review Books).

Kolbert, E. (2014) *The Sixth Extinction: An Unnatural History*. First edition. New York, NY: Henry Holt and Company.

Koselleck, R. (2004) *Futures Past: On the Semantics of Historical Time*. New York, NY: Columbia University Press.

Latour, B. (1993) *We Have Never Been Modern*. Cambridge, MA: Harvard University Press.

Latour, B. (2011) 'It's the Development, Stupid! or How Can we Modernize Modernization', in Nordhaus, T. and Shellenberger, M. (eds) *Love Your Monsters: Post-environmentalism and the Anthropocene*, pp. 17–25.

Latour, B. (2017) *Facing Gaia: Eight Lectures on the New Climatic Regime*. Translated by C. Porter. Cambridge, UK; Medford, MA: Polity.

Lynas, M. (2011) *The God Species: Saving the Planet in the Age of Humans*. Washington, DC: National Geographic.

Marsh, G. P. (1864) *Man and Nature: Or, Physical Geography as Modified by Human Action*. New York, NY: Charles Scribner.

Matheny, J. G. (2007) 'Reducing the Risk of Human Extinction: Reducing the Risk of Human Extinction', *Risk Analysis*, 27(5), pp. 1335–1344. doi: 10.1111/j.1539–6924.2007.00960.x.

McLaren, D. P. (2018) 'Whose Climate and Whose Ethics? Conceptions of Justice in Solar Geoengineering Modelling', *Energy Research & Social Science*, 44, pp. 209–221. doi: 10.1016/j.erss.2018.05.021.

McNeill, J. R. and Engelke, P. (2014) *The Great Acceleration: An Environmental History of the Anthropocene since 1945*. Cambridge, MA: The Belknap Press of Harvard University Press.

Meadows, D. H. (1972) *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*. Edited by Club of Rome. New York, NY: Universe Books.

Meinshausen, M. *et al.* (2017) 'Historical Greenhouse Gas Concentrations for Climate Modelling (CMIP6)', *Geoscientific Model Development*, 10(5), pp. 2057–2116. doi: 10.5194/gmd-10–2057-2017.

Mitchell, T. (2011) *Carbon Democracy: Political Power in the Age of Oil*. London, UK; New York, NY: Verso.

Montoya, J. M., Donohue, I. and Pimm, S. L. (2018) 'Planetary Boundaries for Biodiversity: Implausible Science, Pernicious Policies', *Trends in Ecology & Evolution*, 33(2), pp. 71–73. doi: 10.1016/j.tree.2017.10.004.

Moore, J. W. (2016) *Anthropocene or Capitalocene? Nature, History, and the Crisis of Capitalism*. Oakland, CA: PM Press.

Morton, T. (2018) *Dark Ecology: For a Logic of Future Coexistence*. New York, NY: Columbia University Press.

Mumford, L. (1934) *Technics and Civilization*. New York, NY: Harcourt, Brace and Company.

Noble, S. U. (2018) *Algorithms of Oppression: How Search Engines Reinforce Racism*. New York, NY: New York University Press.

Oxfam (2020) *Time to Care: Unpaid and Underpaid Care Work and the Global Inequality Crisis*. Available at: https://oxfamilibrary.openrepository.com/bitstream/handle/10546/620928/bp-time-to-care-inequality-200120-en.pdf (Accessed: 9 August 2020).

Peters, T. (2007) 'Are We Playing God with Nanoenhancement?', in Allhoff, F. *et al.* (eds) *Nanoethics: The Ethical and Social Implications of Nanotechnology*. Hoboken, NJ: John Wiley & Sons, pp. 173–184.

Polak, F. L. (1973) *The Image of the Future*. Translated by E. Boulding. Amsterdam, Netherlands: Elsevier Scientific Publishing Company.

Raworth, K. (2017) *Doughnut Economics: Seven Ways to Think Like a 21st-century Economist*. London, UK: Random House Business Books.

Rees, M. (2013) 'Denial of Catastrophic Risks', *Science*, 339(6124), pp. 1123–1123. doi: 10.1126/science.1236756.

Rockström, J. *et al.* (2009) 'A Safe Operating Space for Humanity', *Nature*, 461(7263), pp. 472–475. doi: 10.1038/461472a.

Scott, J. C. (1998) *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed*. New Haven, CT: Yale University Press (Yale Agrarian Studies).

Sherlock, R. L. (1922) *Man as a Geological Agent: An Account of His Action on Inanimate Matter*. London, UK: H.F. & G. Witherby.

Sleeboom-Faulkner, M. and Hwang, S. (2012) 'Governance of Stem Cell Research: Public Participation and Decision-making in China, Japan, South Korea and Taiwan', *Social Studies of Science*, 42(5), pp. 684–708. doi: 10.1177/0306312712450939.

Sorkin, A. R. (2011) 'A Hefty Price for Entry to Davos', *The New York Times*, 24 January. Available at: https://dealbook.nytimes.com/2011/01/24/a-hefty-price-for-entry-to-davos/ (Accessed: 9 August 2020).

Star, S. L. and Griesemer, J. R. (1989) 'Institutional Ecology, "Translations" and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907–1939', *Social Studies of Science*, 19(3), pp. 387–420.

Steffen, W. *et al.* (2015) 'The Trajectory of the Anthropocene: The Great Acceleration', *The Anthropocene Review*, 2(1), pp. 81–98. doi: 10.1177/2053019614564785.

Steffen, W., Crutzen, P. J. and McNeill, J. R. (2007) 'The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature', *Ambio*, 36(8), pp. 614–621.

Stubblefield, C. (2018) 'Managing the Planet: The Anthropocene, Good Stewardship, and the Empty Promise of a Solution to Ecological Crisis', *Societies*, 8(2), p. 38. doi: 10.3390/soc8020038.

Swyngedouw, E. and Ernstson, H. (2018) 'Interrupting the Anthropo-obScene: Immuno-biopolitics and Depoliticizing Ontologies in the Anthropocene', *Theory, Culture & Society*, 35(6), pp. 3–30. doi: 10.1177/0263276418757314.

Tantram, J. (2012) 'Promise and Problems in Planetary Boundaries', *The Guardian*, 19 November. Available at: https://www.theguardian.com/sustainable-business/blog/promise-problems-planetary-boundaries (Accessed: 9 August 2020).

Trischler, H. (2016) 'The Anthropocene: A Challenge for the History of Science, Technology, and the Environment', *NTM Zeitschrift für Geschichte der Wissenschaften, Technik und Medizin*, 24(3), pp. 309–335. doi: 10.1007/s00048-016-0146-3.

Vandermoere, F. *et al.* (2010) 'The Morality of Attitudes toward Nanotechnology: About God, Techno-scientific Progress, and Interfering with Nature', *Journal of Nanoparticle Research*, 12(2), pp. 373–381. doi: 10.1007/s11051-009-9809-5.

Verhagen, L. (2018) 'De man met een (geïmplanteerde) antenne voor kleur', *De Volkskrant*, 20 July. Available at: https://www.volkskrant.nl/mensen/de-man-met-een-geimplanteerde-antenne-voor-kleur~b0def06d/ (Accessed: 9 August 2020).

Warde, P., Robin, L., and Sörlin, S. (2018). *The Environment: A History of the Idea*. Baltimore, MD: Johns Hopkins University Press.

Watson, A. and Lenton, J. (2011) *Revolutions That Made the Earth*. Oxford, UK: Oxford University Press.

Winner, L. (1980) 'Do Artifacts Have Politics?', *Deadalus*. (Modern Technology: Problem or Opportunity?), 109(1), pp. 121–136.

World Economic Forum (2016) *The New Plastic Economy: Rethinking the Future of Plastics*. Cologne, Germany; Geneva, Switzerland: World Economic Forum.

Zalasiewicz, J. *et al*. (2017) 'Scale and Diversity of the Physical Technosphere: A Geological Perspective', *The Anthropocene Review*, 4(1), pp. 9–22. doi: 10.1177/2053019616677743.