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Earthing Technology: Towards an Eco-centric Concept of Biomimetic Technologies in the Anthropocene

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Abstract: In this article, we reflect on the conditions under which new technologies emerge in the Anthropocene and raise the question of how to conceptualize sustainable technologies therein. To this end, we explore an eco-centric approach to technology development, called biomimicry. We discuss opposing views on biomimetic technologies, ranging from a still anthropocentric orientation focusing on human management and control of Earth's life-support systems, to a real eco-centric concept of nature, found in the responsive conativity of nature. This concept provides the ontological and the epistemological condition for an eco-centric concept of biomimetic technologies in the Anthropocene. We distinguish five principles for this concept that can guide future technological developments.

Key words: Anthropocene, biomimicry, ecomimesis, philosophy of technology, sustainable technology

Introduction

Philosophy of technology can be criticized for narrowing its scope to concrete artefacts and their uses, thereby neglecting Earth's ecosystem in which these artefacts occur and operate. According to Langdon Winner for instance, philosophers can no longer take the availability of "cheap and readily available petroleum" for granted that "fuels virtually every function of our technological civilization" (Winner 2013). Besides the energy crisis, global warming threatens the existence of a stable, favourable climate on which the functioning of modern technological societies depends. This raises the question not only of how philosophers of

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technology should respond to the changing environment in which technologies operate, but also of how we as a society should attune our future technologies to this new situation. Should philosophers of technology and STS scholars assume a more ecological or even eco-centric focus, instead of focusing on technical artefacts or (socio)technical systems only?

In this article, we reflect on these changed conditions under which new technologies emerge—energy crisis, global warming and so forth—in order to answer these questions. In section one, we conceptualize these changed conditions of the current age in terms of the Anthropocene; the Anthropocene is a new geological epoch, in which the human has become the most influential 'terraforming' factor on Earth. Global warming is one of the main characteristics of the Anthropocene. On the one hand, it shows our dependence on Earth's carrying capacity for our human existence. This, on the other hand, calls for the transition to a more sustainable future, including sustainable technologies. This raises the question of how to conceptualize sustainable technology in the Anthropocene.

In section two, we explore a more eco-centric approach to technology development, called biomimicry or bio-inspiration. Biomimicry or biomimetics is "a new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems" (Benyus 2002, 1). Biomimicry can be considered an eco-centric approach of technology development, because it takes the *bios*, nature or the eco-systems of planet earth as point of departure in the development of new technologies. According to Janine Benyus, one of the founding mothers of the biomimetic movement, *homo industrialis* has reached the limits of Earth's carrying capacity and is "hungry for instructions about how to live sanely and sustainably on the Earth" (Benyus 2002, 1). Biomimicry provides a potentially new and ecosystem-friendly approach to technology development, which is no longer characterized by the domination and exploitation of nature, but by learning and exploration (Myers 2012; Forbes 2005). Benyus for instance argues that the first industrial revolution is characterized by the domination and exploitation of nature, whereas the second—biomimetical—industrial revolution is characterized by learning from, and exploring, nature (Blok and Gremmen 2016).

We discuss opposing views on biomimetic technologies in the Anthropocene, ranging from an anthropocentric orientation with a strong focus on human management and control of Earth's life-support systems (section 2), to an eco-centric orientation in which the earth and human agency become intertwined. With an eco-centric orientation of biomimetic technologies, we mean that natural agency informs biomimetic technologies, without committing a priori to the anthropocentric context in which they are applied. The point of departure of such an eco-centric approach is found in the responsive conativity of nature, and involves a dualist notion of nature—nature as undifferentiated materiality and nature as differentiated natural-technological hybrids (section 3). The advantage of this dualist concept of nature is that it enables us to acknowledge the immanence of thinking in the physical in the Anthropocene while at the same time acknowledging an asymmetry between nature and (human) technology. We will show that this concept of nature provides the ontological and the epistemological condition for an eco-centric concept of biomimetic technologies in the Anthropocene. We distinguish five principles or conditions for an eco-centric concept of biomimetic technologies that can claim to provide an ecosystem-friendly approach to technology and should guide future technological developments in the Anthropocene. In section 4, we draw conclusions and reflect on the implications of this concept of biomimetic technologies for human agency in the Anthropocene.

1. The Changed Conditions of Technology in the Anthropocene

The changed conditions in which we currently live can be conceptualized as the Anthropocene. According to atmospheric- and geo-scientists like Will Steffen and Paul Crutzen, humans have increasingly become a geophysical force since the industrial revolution (Steffen et al. 2007). According to Crutzen, the Anthropocene can be defined as the geological epoch supplementing the Holocene—the warm period of the last ten to twelve millennia—which is dominated by humans (Crutzen 2002); or, more precisely, the epoch in which the geological conditions and processes of Earth's life-support systems have been profoundly altered by human activity. Examples of human influence on Earth's dynamics and future states are erosion due to deforestation, agriculture, global warming, the chemical composition of soils, seas and the atmosphere.

The first occurrence of human impact on the natural environment did not take place during the industrial revolution. Since the Neolithic for instance, humans have modified landscapes by agricultural practices and predation of animals. Nevertheless, "the human imprint on the environment may have been discernible at local, regional, and even continental scales, but preindustrial humans did not have the technological or organizational capability to match or dominate the great forces of nature" (Steffen et al. 2007, 614). Most Anthropocenologues argue that the starting point of the Anthropocene is found in the industrialization of society around 1800, because the exponential increase in the use of fossil fuels had an enormous impact on Earth's systems and accelerated in the phase after the Second World War, resulting in the global economy we know today (Steffen et al. 2007). In contrast with the age of modernity, in which humanity was conceptualized as *opposed* to and transcending the natural environment, Earth becomes humanized and the human becomes naturalized in the Anthropocene. "The Anthropocene represents a new phase in the history of both humankind and of the Earth, when natural forces and human forces became intertwined, so that the fate of one determines the fate of the other" (Zalasiewicz et al. 2010, 2231). Humanity can no longer be conceived without the natural and technological environment on which it depends, and Earth's planetary population by humans makes it impossible to conceptualize nature without human cultivation, preservation and development.

Because it is becoming increasingly clear nowadays that humanity is using more natural resources than Earth can provide, and that we need two or more planets to support our modern way of living in the future, the third phase of the current Anthropocene should consist in human stewardship of Earth in order to ensure the sustainability of Earth's life-support systems for human life on earth. In this respect, the term Anthropocene not only describes our current situation but primarily sensitizes us to the idea that we have to take responsibility for Earth's sustainability (Kolbert 2011). The Anthropocene provides a radical new opportunity for such stewardship, because it overthrows classical dichotomies like nature-technology or nature-culture: "The long-held barriers between nature and culture are breaking down. It's no longer us against 'Nature.' Instead, it's we who decide what nature is and what it will be. . . . Living up to the Anthropocene means building a culture that grows with Earth's biological wealth instead of depleting it. Remember, in this new era, *nature is us*" (Crutzen and Schwägerl 2011).

Although the official confirmation that Earth has entered a new geological epoch has still to be issued by the *International Commission on Stratigraphy*, the concept of the Anthropocene has been taken up by philosophers like Bruno Latour and Timothy Morton. For Morton, the idea that nature is us becomes very concrete in his experience of global warming. Nowadays, the evidence for global warming is so massive that there is no longer a position possible outside of it; whereas in earlier ages, it was possible to externalize waste to the environment, we nowadays realize that every externalization returns like a boomerang and impacts Earth's life-support systems (Morton 2013). Framed in more philosophical terms, the experience of global warming is the experience of the whole of being, in which the one who experiences this whole is included.[1] Phenomena like global warming provide the experience that all of Earth is an 'interior space' without any possible position outside of it (Sloterdijk 2009), forcing "us to acknowledge the immanence of thinking to the physical" (Morton 2013, 2). So whereas philosophers like Nietzsche saw the "de-anthropomorphizing of nature and the re-naturalizing of man" as the primary objective of their philosophical work (Nietzsche 1988, 201), the factual experience of the Anthropocene concerns not only the ontic experience of our dependence on the biosphere, but also the ontological experience of the immanence of thinking to Earth. It primarily concerns the identity of both human existence and Earth's natural environment. Contrary to the characteristic of human existence as opposed to and transcending nature, this ontic-ontological experience of the whole of being in which human existence is included, i.e., the experience that we live on Earth and *as* Earth, characterizes the Anthropocene epoch.

This brings us to the following question. If the current phase of the Anthropocene demands a human stewardship of Earth in order to ensure the sustainability of Earth's life-support systems on the one hand, while the Anthropocene on the other hand shows the immanence of thinking to the physical, what then exactly is the role of human agency in general, and of human technology in particular? What does it mean to *exist* in the Anthropocene?

2. The Eco-Mimesis of Technology in the Anthropocene: Contested Conceptualizations

Scholars like Crutzen and colleagues still see a significant role for human agency in the stewardship of Earth: "We should adapt our culture to sustaining what can be called the 'world organism.' This phrase was not coined by an esoteric Gaia guru, but by eminent German scientist Alexander von Humboldt some 200 years ago. Humboldt wanted us to see how deeply interlinked our lives are with the richness of nature, hoping that we would grow our capacities as a part of this world organism, not at its cost. His message suggests we should shift our mission from crusade to management, so we can steer nature's course symbiotically instead of enslaving the formerly natural world" (Crutzen and Schwägerl 2011). In this view, the sustainability of Earth's life-support systems is threatened by global warming, and human agency is needed to manage the course of nature. Crutzen argues for a *symbiotic* way of steering nature's course, "that grows with Earth's biological wealth instead of depleting it" (Crutzen and Schwägerl 2011).

This symbiotic way of steering nature's course can be conceptualized as biomimicry or biomimesis.[2] According to Peter Sloterdijk, recent developments in technology and science, like biotechnology and synthetic biology, show that they are not purely natural or technological, but rather hybrid forms of technology that are similar to nature: *homeo*-technology (derived from *homeo-*, 'similar,' 'alike'). With this, we are on the "threshold of a form of technology that will be sufficiently developed to enable us to radically imitate nature" (Sloterdijk and Heinrichs 2006, 329). In biomimicry, technological developments imitate or take inspiration from the operating principles of nature, like "nature runs on sunlight," "nature fits form to function," "nature recycles everything" (Benyus 2002). It studies the design of natural systems—the ability of geckos to climb overhanging walls with the help of toepads with millions of hairs that can conform to surfaces—and then imitates these designs to solve human problems; the ability to attach objects to, and detach objects from, the wall, gecko tape and so on. Proponents of biomimicry claim that it provides an alternative for the *homo industrialis* who primarily exploited the natural environment, and consists in exploring and learning from nature about how to live and act in a sustainable way. Nature's instructions for living sustainably on Earth are found in 3.8 billion years of evolution, in which plants and animals developed the ability to fly, capture energy, see and hear, and so on. "In short, living things have done everything we want to do, without guzzling fossil fuel, polluting the planet, or mortgaging their future. What better models could there be?" (Benyus 2002, 2). To the extent that biomimetic technology acts and performs in accordance with the operating principles of nature, it can claim to be a symbiotic management approach to nature's course and to grow with Earth's biological wealth (Benyus 2002).

Although biomimetic technologies can be considered *symbiotic* to nature's own design principles, they presuppose at the same time an anthropocentric position of human agency. From the perspective of Crutzen's call for stewardship of Earth in the third phase of the Anthropocene for instance, it is clear that nature is dependent on the good management of human agency: "it's we who decide what nature is and will be" (Crutzen and Schwägerl 2011), and this entails the obligation to take care of Earth's future. A similar role of human agency can be traced in the literature on biomimicry.

This anthropocentric position also becomes clear in Benyus's focus on engineering, and in this respect, on 'human' problems that should be solved by technology: "biomimicry is the conscious *emulation* of life's genius" (Benyus 2002, 2) (emphasis added). *Emulation* of nature means not only *imitation* but also *competition* with nature, for instance in the built environment. In Sloterdijk's concept of biomimicry (homeo-technology), the anthropocentric position of human agency becomes clear in his belief that the integration of the biosphere and the technosphere under the direction and guidance by human cognition can guarantee a sustainable future (Sloterdijk 2001).

The paradoxical result of the anthropocentric orientation of biomimetic technologies in the Anthropocene is that human agency on the one hand mimics "nature's biological wealth instead of depleting it," while, on the other hand, nature is seen as a patient without agency, dependent on human technology and management. In fact, biomimetic technologies in the Anthropocene not only *mimic* nature, but also *perfect* nature, which it cannot do itself. Or as Forbes puts it: "Bio-inspiration is the new science that seeks to use nature's principles to create things that evolution never achieved" (Forbes 2005, 1).

These two forms of biomimicry as imitation and perfection of nature can be traced back to the metaphysical tradition. In Aristotle's *Physics*, we can find the classical definition of the concept of *mimesis*, from which the concept of biomimicry is derived. According to Aristotle, technology and nature are essentially the same because technology mimics nature (Aristotle 1980). Technology either—on the basis of nature—accomplishes or perfects what nature is not capable of effectuating itself or imitates (*mimeitai—mimesis*) nature. There are, therefore, two types of the technological *mimesis* of nature according to Aristotle. First of all, there is the mimetic copy or reproduction of the naturally given, and secondly, there is another type of *mimesis* based on the deficiency of nature. Nature is not capable of producing or effectuating everything, and, in this case, mimicry productively supplements the capabilities of nature (Lacoue-Labarthe 1998; Blok and Gremmen 2016).[3]

Biomimicry as perfection of nature presupposes a deficiency in nature. In the Anthropocene, this deficiency can be conceptualized as Earth's inability to accommodate an increasing world population *and* ensure the sustainability of Earth's life-support systems at the same time. It is for this reason that nature has to be supplemented by technology, for instance by mitigating or geo-engineering strategies to secure the sustainability of Earth's life-support systems. Or, as the environmental scientist Erle Ellis puts it: "It is no longer Mother Nature who will care for us, but us who must care for her. . . . We most certainly can create a better Anthropocene. We have really only just begun, and our knowledge and power have never been greater. We will need to work together with each other and the planet in novel ways. . . . In the Anthropocene we are the creators, engineers and permanent global stewards of a sustainable human nature" (Ellis 2011, 27).

There are at least two reasons to question the anthropocentric orientation of biomimetic technologies in the Anthropocene. We can argue that the exploitation of Earth in the industrial age is rooted in such anthropocentric humanism, i.e., in the standpoint of mastery of the human will to master and exploit the natural world as a commodity for human needs (Blok 2015). According to environmental philosophers like Plumwood, the assumption of a fundamental dualism between nature and human agency gave rise to the idea that human agency can solve the environmental crisis we face today by engineering and technology (Plumwood 2002), which in fact consists in the exploitation of nature (Sloterdijk and Heinrichs 2006). This bias of anthropocentrism is also confirmed in many examples of biomimetic practices that just pretend to integrate life in order to sustain the planet but can be characterized as enslaving the formerly natural world. One can think for instance of the Oyster-techture, in which oysters are exploited to build wave-attenuating reefs to protect the shore from wind, filtering water and so on, or the introduction of genetically modified bio-luminescent trees, in which trees are used to illuminate city-centre streets for instance (Myers 2012). The difficulty in distinguishing between symbiotic approaches and enslaving approaches is that both presuppose an anthropocentric role of human agency as the manager of Earth's natural resources (Blok 2015).

The same primacy of human agency can be found in the discourse on the Anthropocene. In his insightful article, Jeremy Baskin has shown that proponents of the Anthropocene argue for planetary engineering and management of the humanized Earth (Baskin 2015). Whereas the mitigation strategy attempts to improve technology and management of natural resources to take the human pressure off Earth's life-support systems, the geo-engineering strategy introduces radical new technologies and control systems to save the planet, like anthropogenic emissions of aerosol particles into the atmosphere to counter greenhouse gas effects, the sequestration of CO_2 in underground reservoirs and so on (Steffen et al. 2007). Baskin comes to the following conclusion:

> The idea (and the evidence) that humanity is now the dominant earth-shaping force combines with the data showing that the condition of the patient is serious, possibly terminal. Humanity and its planet are now in a critical and exceptional state. This both generates and draws upon an attraction to global-scale technological 'solutions' and earth management, under the guidance of the scientists-engineers best placed to understand, interpret and help shape the necessary interventions. These are responses aimed either at bringing us back from the brink, or at taking us to a new and better-managed future Earth. In both versions, the Anthropocene is both diagnosis and cure, both description and prescription. (Baskin 2015, 22)

In other words, it is questionable whether biomimetic technologies really can claim a symbiotic way of managing nature's course, instead of enslaving the natural world, as long as the point of departure is found in an anthropocentric position of human agency as the manager of Earth's life-support systems. At the same time, it is exactly the experience of the Anthropocene that shows the impossibility of such an anthropocentric position of human agency and can initiate the transition from a conceptualization of humans-as-opposed-to-nature to a conceptualization of human existence as living-on-Earth-and-as-Earth, as we have seen in the previous section. This is the first reason to reject the anthropocentric orientation of biomimetic technologies in the Anthropocene and to consider a more eco-centric orientation.

A second reason is that, however true it may be that humanity currently has a significant impact on Earth's dynamics, scientific findings make it increasingly clear that Earth's systems themselves are inherently unstable and characterized by transformation, change and volatility: "Whatever 'we' do, ice cores and other proxies of past climate profess to us, our planet is capable of taking us by surprise. With or without the destabilizing surcharge of human activities, the conditions most of us take for granted could be taken away, quite suddenly, and with very little warning" (Clark 2011, xi). A phenomenon like global warming shows on the one hand that humans in fact have a significant role in Earth's history, but on the other hand precisely diminishes the role of human agency because it displaces human existence from the centre of Earth's historical development and leaves us embarrassed regarding the question of what in fact the role of human agency is in the Anthropocene (Morton 2013).[4] It is questionable whether human agency can claim to manage nature's course in the Anthropocene, to say the least; deep geological time convinces us, on the contrary, of the eco-centrism of the preconditions for human agency, i.e., the significance of Earth's systems on which human agents and their technologies entirely depend. In the Anthropocene, it is increasingly acknowledged that Earth is not only the ontic condition of the possibility for the emergence of a world in which humanity is the manager of the natural resources (Blok 2016), but also the ontological condition out of which human life emerges (Blok 2015), as we shall see in the next section. This is the second reason to reject an anthropocentric orientation of biomimetic technologies in the Anthropocene and to consider a more eco-centric orientation.

In the next section, we take this rejection of anthropocentrism as a call to take the idea that *nature is us* more serious, and to explore a natural concept of nature, which serves as a point of departure for our 'earthing' technology, i.e., for an eco-centric but still dualist concept of biomimetic technologies in the Anthropocene.

3. Earthing Technology: Towards an Eco-Centric Concept of Biomimetic Technologies[5]

With an eco-centric orientation of biomimetic technologies, we mean that nature itself and natural agency informs our concept of biomimetic technologies, without committing a priori to the anthropocentric context in which they are applied. In order to develop such an eco-centric orientation of biomimetic technologies in the Anthropocene, we can already draw the negative conclusion that our efforts to earth technology by developing an eco-centric notion of biomimicry is in no way comparable to the anthropocentric conceptualization. To the extent that current biomimetic practices are inspired by such an anthropocentric notion of biomimicry, an eco-centric concept of biomimicry does not necessarily align with the way current biomimetic practices proceed. On the contrary, our eco-centric concept of biomimetic technologies contains a call to earth technology in the third phase of the Anthropocene and provides guidelines for *future* biomimetic technologies.

We therefore first ask which concept of nature should be at stake in an eco-centric orientation of biomimetic technologies in the Anthropocene. The starting point for our considerations is found in an early philosophical insight that is nowadays increasingly accepted in science: the idea that not only humans, but all things, have agency (Latour 1993). One of the origins of this idea can be found in the work of Spinoza.[6] According to Spinoza, "each thing, as far as it can by its own power, strives [*conatur*] to persevere in its own being" (Spinoza 1992, part 3 proposition 6). For Spinoza, this conativity is not an *ontic* will or impulse of living systems towards self-preservation, but an *ontological* principle of all beings: "The conatus to preserve itself is the very *essence* of a thing" (Spinoza 1992, part 3 proposition 7) (emphasis added); conativity is a 'cosmogenic' or world-building capacity of nature itself to articulate and establish the being or *identity* of beings. Furthermore, for Spinoza, this conativity is not limited to *living systems*, because *every* body is conative according to Spinoza. On the one hand, we can argue that conativity is not only a principle of living nature, but primarily a principle of matter, i.e., of each material body on Earth.[7] On the other hand, we can argue that this concept of conativity of material entities extends the domain of the 'living' from the traditional animate to the 'inanimate,' i.e., 'living matter' as key element in the generation and self-regulation of Earth as a dynamic system (Vernadsky 1998; Lovelock 2006; Clark 2011).[8] In this article, we therefore conceive conativity as a principle of Earth's materiality, thus including nature. As a consequence, our concept of biomimicry is not confined to the mimesis of 'living' nature, as seems to be the case in Dicks's (2016) work, and should be considered as eco-mimesis.[9]

To what extent can we consider conativity to be *essential* for natural entities, i.e., to what extent does conativity articulate the identity of natural entities? In Spinoza's view, only one common substance—*Deus sive Natura*—constitutes the universe. All natural entities that we encounter in the world are *modes* or *modifications* of this one substance. As such a mode, each material entity is resistant to everything that can take its existence away, and this resistance is precisely the conativity or striving to preserve oneself as such a mode of the common substance (Spinoza 1992, part 3 proposition 6). Conativity is essential then because it *differentiates* the identity of natural entities from the common but undifferentiated substance—it articulates and establishes the self or identity of the tree and the stone for instance *as* modes of nature (*self*-perseverance)—and prevents at the same time their relapse into this common substance (self-*perseverance*).

If we frame Spinoza's idea of a common substance in more profane terms and highlight the 'naturalistic' framework that he introduces, we can say that all natural entities that we encounter in the world—the stone, the tree, human beings—are modes or modifications of nature. As such a modification of nature, each natural entity strives to preserve itself (self-perseverance). If, however, this striving is *essential* for each natural entity, conativity cannot be understood at an ontic level as a struggle for the existence of these entities, but at an ontological level as the impulse[10] in nature to differentiate and establish the identity of natural entities like stones and trees as modes of this undifferentiated nature.

The essentiality of conativity for natural entities shows in other words that conativity is not a will or power of natural entities to preserve themselves (*autopoiesis*) but primarily a principle by which nature becomes delimited *as* stone, tree and so on. Conativity is literally an endeavouring, an effort; and the essentiality of conativity consists in its endeavour to articulate and establish the differentiated identity of natural entities *as* modes of undifferentiated nature. On the one hand, conativity is needed to differentiate and establish these natural entities from undifferentiated nature in which they are embedded ('self'-perseverance). On the other hand, conativity is needed to maintain and persevere these differentiations and prevent their relapse into undifferentiated nature again (self-'perseverance'). These two aspects of conativity are also confirmed by recent insights into Earth and life sciences; Earth's history is characterized by an inherent instability in which life forms but also inanimate conditions of life like climate changes emerge, adapt to the changing environment and disappear again: "The vision that has been emerging, through a succession of discoveries, controversies and convergences, is one in which instability and upheaval, rhythmical movement and dramatic changes of state are ordinary aspects of the earth's own history" (Clark 2011, xii). The inherent instability of nature indicates undifferentiated nature, out of which differentiated nature or relatively stable bodies like stones and trees emerge ('self'-perseverance) and maintain (self-'perseverance') themselves. With this, a dualistic notion of nature appears—undifferentiated nature and differentiated nature - in which undifferentiated nature is the origin of differentiated nature like stones and trees.[11]

A first round of reflection on a naturalist concept of conativity makes clear that conativity primarily consists in the articulation and establishment of the self- or identity of natural entities as differentiations from undifferentiated nature. This is the first characteristic of conativity that we can discern as a principle of nature.

What is the consequence of this principle of conativity of nature for an eco-centric orientation of biomimetic technologies? It implies that precisely these two aspects of the conativity of nature ('self'-perseverance or self-assertion and self-'perseverance' or self-preservation) are mimicked in eco-mimetic technologies. The advantage of conceptualizing the conativity of nature in terms of self-perseverance is that an eco-mimesis of this conativity consists in the articulation and perseverance of the self or identity of natural-technological hybrids. Just like the self or identity of natural entities are differentiated from undifferentiated nature, eco-mimetic technologies are differentiations of undifferentiated nature and form natural-technological hybrids as such differentiations of undifferentiated nature. Eco-mimetic 'self'-perseverance can be understood as the articulation of the self or identity of natural-technological hybrids (self-organization and self-design) and associated with the autonomy, adaptability and headstrongness in their growth, whereas eco-mimetic self-'perseverance' can be understood as self-regulation and as the self-healing or self-repairing capacity of natural-technological hybrids. What is primarily mimicked in an eco-centric orientation of biomimetic technologies is nature's conativity—a conato-mimesis—that results in conative natural-technological hybrids.

With this, the eco-centric orientation of biomimetic technologies turns out to be different from the conceptualization of technology as instrument in the hand of human beings to control and manage Earth's life-support systems (Crutzen, Ellis, etc.). An example can be found in eco-mimetic bio-robotics or artificial intelligence, in which not only specific human functions are mimicked and perfected, but especially capabilities associated with self-perseverance (self-organisation, autonomy, self-regulation etc.). Another example is a biorefinery in which bacteria, waste streams and humans are interconnected and form 'living machines' (Todd and Todd 1994). The consequence of an eco-centric orientation of such bio-mimetic technologies is, however, that we have to acknowledge the independence and agency of natural-technological hybrids, their uncertainty and unpredictability. On the one hand, eco-mimetic technologies in the Anthropocene are natural-technological hybrids characterized by agency (self-perseverance) and therefore on the other hand beyond human control. The agency of things already implies that nature itself does not always serve our agenda and withdraws from our control (Latour 1993). The incorporation of the conativity of nature in our technological design extends this uncontrollability to natural-technological hybrids and increases the autonomy, as well as the uncertainty and unpredictability of their future development. The lack of control is already at stake in current technologies like smartphones and internet, but will increase in case of eco-mimetic technologies like bio-robotics or biomimetic artificial intelligence.The lack of (human) control is the price we have to pay for the eco-centric orientation of biomimetic technologies in the Anthropocene.

Let us consider now a further consequence of conativity as the articulation of the identity of natural entities as differentiations of undifferentiated nature: 'I' am not primarily conative but 'I' am the performative constituent of the conativity of nature. This means that conativity as a principle of nature consists in the endeavour to differentiate and preserve natural entities like stones and trees, me and you, from undifferentiated nature as modes of nature, which remain embedded in this conative or 'vibrant' materiality of nature (Bennett 2010). We can compare this endeavour to differentiate with Kauffman's ideas about the *origins of order*, i.e., the spontaneous emergence of order out of chaos by the self-organization of complex biological systems (Kauffman 1993). This reveals a second characteristic of the conativity of nature: undifferentiated nature itself is a non-identity—or chaos in Kauffman's terms—that articulates the identity of natural entities—or order in Kauffman's terms—without the possibility of being identified itself. Nature itself is always heterogeneous to, and always transcends, the identity of actual natural entities as differentiations (order) from undifferentiated nature (chaos).

With this, our dualist concept of nature is further articulated. Undifferentiated nature concerns non-identity whereas differentiated nature concerns the identity of natural entities. This dualist notion of nature implies a fundamental limitation of any eco-centric orientation of biomimetic technologies; nature (as non-identity) is always heterogeneous to the eco-mimetic articulation of natural-technological hybrids in the Anthropocene. The advantage of this dualist concept of nature is that it enables us to acknowledge the immanence of thinking in the physical in the Anthropocene—i.e., immanent nature, which is the starting point of any eco-centric orientation of biomimetic technologies—while at the same time acknowledging the fundamental asymmetry between (undifferentiated) nature and (differentiated) natural-technological hybrids. This asymmetry is not only an epistemic limitation of what is known—Earth as *terra incognita*—but also an ontological asymmetry. Aristotle argued that *steresis* or absencing belongs to the self-emergence of nature. This tendency of nature to withdraw itself can be found in the hardness and impenetrability of the things around us—the self-closedness of a stone—but also in undifferentiated nature from which the identity of natural entities emerges, stabilizes and into which they recede again (Blok 2016). In other words, this dualist concept of nature enables us to acknowledge a radical asymmetry between (undifferentiated) nature and (differentiated) natural-technological hybrids, without reintroducing the classical dichotomy between nature and technology. On the contrary, it enables us to acknowledge both immanent nature, which is mimicked in an eco-centric orientation of biomimetic technologies, and the complexity and heterogeneity of nature, which puts a limit to our ambition to mimic and incorporate nature.

A further advantage of such a dualist concept of nature is that it enables us to acknowledge the fundamental possibility of failure of biomimetic technology. Authors like Benyus and Sloterdijk sometimes suggest that biomimicry is intrinsically or ethically 'good' (Sloterdijk 2001, 230–31). At the same time, it is clear that design can be misused and that designers can be biased or frail and use their power for their own purposes (Myers 2012). This possibility of failure does not, however, necessarily have to be found in a dichotomy between nature—understood as somehow intrinsically good—and human technology—which may turn out to be fallible. A dualist concept of nature may explain why biomimetic technologies sometimes fail. An eco-centric orientation of biomimetic technologies aims to mimic and even incorporate nature's principles in the development of natural-technological hybrids, but, because nature withdraws itself both at an epistemic and an ontological level, biomimetic technologies become fundamentally fallible because of missteps, misuse or controversy. At the lowest level of consideration, it may turn out that they mimic the identity of natural entities that are still emerging or entities that in fact have already receded into undifferentiated nature for instance; Earth's system itself is inherently unstable and characterized by transformation, change and volatility as we have seen. In general however, we can state that eco-mimetic natural-technological hybrids are fallible because they try to mimic something that is beyond their control. This acknowledgement of the uncontrollability of nature and, with this, the fallibility of natural-technological hybrids seems to be highly relevant in the 'risk society' in which we currently live (Beck 1992), in which our ability to make final judgments about the future impact of present technologies is fundamentally limited. This fallibility of technologies is the price we have to pay for an eco-centric orientation of biomimetic technologies in the Anthropocene.

If we conceive conativity as a principle of nature, rather than as a principle of natural entities, the question is why undifferentiated nature differentiates natural entities like stones, trees and human beings that build Earth's eco-systems.

According to Spinoza, nature is not only conative but also *associative*; this means not only that the conativity of nature articulates and establishes natural entities as modes of nature that can affect other entities in the environment, but also that these entities are in this at the same time *affected* by other entities, which are in their turn also constituted by the conativity of nature. According to Spinoza, each mode of nature is already a composition of simple modes, which affect and are affected by one another, i.e., which are primarily *responsive* to one another and form the relatively stable bodies we encounter in the world, ranging from simple bodies like stones and human beings to complex networks and alliances of bodies like Earth's ecosystems. Or as Jane Bennett puts it: "because each mode suffers the actions on it by other modes, actions that disrupt the relation of movement and rest characterizing each mode, every mode, if it is to persist, must seek new encounters to creatively compensate for the alterations or affections it suffers. What it means to be a 'mode,' then, is to form alliances and enter assemblages: it is to mod(e)ify and be modified by others" (Bennett 2010, 22).

If we conceptualize this associativity at an ontological level, i.e., at the level of undifferentiated nature that articulates and establishes the identity of natural entities, these entities are not only the product of the conativity of nature, because this conativity is at the same time responsive to the conativity of (other) differentiated nature.[12] This responsive conativity of nature articulates the relatively stable bodies like stones, trees and animals that form Earth's eco-systems. In other words, in the differentiation of natural entities by the conativity *of* nature, these entities are at the same time constituted by their responsiveness *to* the conativity of (other) nature and build the relatively stable bodies and complex systems in which the identity of natural entities are interconnected and interdependent. A second round of reflexion on a naturalist concept of conativity reveals the responsiveness of conativity as a third characteristic of the conativity of nature.

This third characteristic of the conativity of nature casts the first characteristic—its self-perseverance—in a new light. Self-perseverance can still give the impression that nature is characterized by self-regulation and the avoidance of the transgression of these limits (*restrictive* nature), but the associative responsiveness of conativity to (other) nature makes clear that self-perseverance is also the source of every new configuration and new differentiation of the identity of natural entities in the environment. This generativity of new differentiations does not only consist in the constitution of simple modes of nature that are characterized by self-perseverance and therefore simply grow. Because they are already affecting and affected by other modes, the conativity of nature results in the differentiation of new and more complex modes, for instance natural-technological hybrids and the eco-systems in which they are embedded.

As a consequence, an eco-centric orientation of biomimetic technologies is characterized not only by conativity as self-perseverance, but at the same time by responsiveness to the conativity of (other) nature. In this responsive conativity, natural-technological hybrids are constituted, but also grow and differentiate adjusted or new hybrids, which in the end recede into undifferentiated nature again. This responsiveness of natural-technological hybrids to the conativity of nature does not remove the asymmetry between (undifferentiated) nature and natural-technological hybrids but rather reinforces this asymmetry. On the one hand, the eco-centric orientation of biomimetic technologies acknowledges the instability of nature, which differentiates natural entities—ranging from stones and trees to the complex eco-systems and atmospheric and biological conditions of life—without expecting any 'return' by human agency as manager (Bataille 1991); the cosmogenic act of nature constitutes the conditions of the possibility on which human existence, including natural-technological hybrids, entirely depends. Because of this dependence, on the other hand, the eco-centric orientation of biomimetic technologies is precisely *responsive* to the conativity of nature, i.e., to its cosmogenic activity, which constitutes the conditions on which these natural-technological hybrids depend. An eco-centric orientation of biomimetic technologies prevents us from focusing on the self-perseverance of an isolated natural-technological hybrid, without any responsiveness to the wider ecological context in which these hybrids emerge and fade away, ranging from the eco-systems in which they are embedded to the dynamic systems on which they depend at both the ontological and the epistemological level. The constitution of natural-technological hybrids serves the sustainability of Earth's life-support systems, but is at the same time aware that the conditions on which they depend are not part of their jurisdiction and that changes and transformations of nature can suddenly withdraw this support without consulting us. Or as Clark puts it: "We cannot simply excavate, render transparent, or recompose the messy, unstable, even violent play of material forces out of which we ourselves have emerged. And this means that alongside our capacity for action, the very condition of our active orientations in the world is a kind of primordial passivity, a susceptibility in the face of all that is not ours to make or even know" (Clark 2011, 52). This passivity of natural-technological hybrids regarding the support of Earth, irrespective of their agency to take care of the future of the planet, is the price we have to pay for an eco-centric concept of biomimetic technologies in the Anthropocene.

In Table 1, the findings regarding the principle of conativity as principle of nature and its translation in five principles of an eco-centric orientation of biomimetic technologies are summarized.

4. Conclusion

The aim of this article was to broaden the perspective of philosophy of technology and to include the ontological conditions under which new technologies emerge and are used. In the current age, these conditions can be defined in terms of the Anthropocene. We have seen that, if we take the idea seriously that, in the Anthropocene, nature is us, it unsettles self-evident dichotomies like nature-technology and nature-human in which technology is normally understood. At the same time, the Anthropocene opens an ontological dimension out of which current and future technologies have to be understood; if we take this ontological dimension seriously, we have to acknowledge that, in the Anthropocene, technology should be earthed and conceived as eco-mimetic.

Next, we raised the question of how eco-mimetic technologies have to be understood under the conditions of the Anthropocene, i.e., how they are attuned with Earth's eco-systems. In section 2, and we discussed opposing views on the bio- or eco-mimesis of technology. Having rejected an anthropocentric orientation of biomimetic technologies in section 2, we reflected on an eco-centric but at the same time dualist concept of nature as the ontological and epistemological condition for an eco-centric concept of biomimetic technologies in the Anthropocene in section 3. We defined five principles of eco-mimetic technologies in the Anthropocene; this enabled us to find an alternative for the anthropocentric orientation with a focus on the management and control of Earth's life-support systems. It is

Table 1: Five principles of an eco-centric orientation of biomimetic technologies in the Anthropocene

Principle of conativity as principle of nature	**Principles of an eco-centric orientation of biomimetic technologies in the Anthropocene**	**Consequences for human agency in the Anthropocene**
Consists in the articulation and establishment of the identity of natural entities as differentiations from undifferentiated nature (*self*-perseverance) and the prevention of their relapse into undifferentiated nature again (self-*perseverance*)	Eco-mimetic technologies incorporate the *self*-perseverance of nature, in which the self or identity of natural-technological hybrids is constituted (self-organization, self-design) Eco-mimetic technologies incorporate the self-*perseverance* of nature, in which the self-regulation, self-healing/self-repairing and adaptability of natural-technological hybrids to new or changing circumstances is constituted	The self-organization of natural-technological hybrids implies the acknowledgement of the agency, relative autonomy and headstrongness of these hybrids Eco-mimetic technologies are no longer instruments in the hand of human being to control and manage Earth's life-support systems, but uncertain, unpredictable and beyond (complete) human control
Withdraws itself (non-identity) in the articulation and establishment of the identity of natural entities	Eco-mimetic technologies acknowledge both immanent nature, which may be mimicked in natural-technological hybrids, and transcendent nature, which puts a limit to our ambition to mimic nature in our technological design	Eco-mimetic technologies are not intrinsically good but are fallible and may be biased Fallibility and biases are not necessarily due to human agency, but may also be due to the instability and volatility of nature itself The uncontrollability of (undifferentiated) nature limits human agency in the management and control of Earth's life-support systems
In the articulation of the self or identity of natural entities (differentiated nature), undifferentiated nature is responsive to the conativity of (other) nature and builds the eco-systems in which the identity of natural entities are interconnected and interdependent	The self-perseverance of eco-mimetic technologies is responsive to the conativity of (other) nature in the generation and articulation of new, adjusted and more complex natural-technological hybrids Responsiveness of biomimetic technologies consists in the responsiveness to the wider ecological context on which the existence of these natural-technological hybrids depends	Eco-mimetic technologies are characterized by a primordial passivity, because they are primarily responsive to the conativity of nature Eco-mimetic technologies serve the sustainability of Earth's life-support systems, notwithstanding the fact that the ecological conditions on which they depend do not fall under their jurisdiction (acknowledgement of the asymmetry between (undifferentiated) nature and natural-technological hybrids)

clear that these five principles do not necessarily align with the way current biomimetic practices proceed. On the contrary, our eco-centric concept of biomimetic technologies contains a call to earth future technologies in the Anthropocene, i.e., provides guidelines for future eco-mimetic technologies. On the one hand, these five principles can guide future technology development in the Anthropocene. On the other hand, these future technologies can claim to be more ecosystem friendly. In what way?

The experience of global warming primarily brings us 'down to earth.' This means, first, that global warming provides an experience of the whole of being in which we are included. This experience forces us to leave the anthropocentric orientation of human biomimetic agency behind. This primordial 'passivity' of human agency corresponds with a primordial openness and responsiveness to the conativity of nature, in which natural-technological hybrids are performatively constituted. This 'passivity' of human agency, however, goes hand in hand with a biomimetic 'activity,' namely, the articulation and establishment of natural-technological hybrids ('self'-perseverance), which are responsive to the ecological context on which their existence—i.e., their self-'perseverance'—depends. By articulating and establishing these natural-technological hybrids, human agency performs a eco-mimesis in which its identity as responsive to the conativity of (other) nature is constituted ('self'-perseverance) and maintained (self-'perseverance') by attuning the development of eco-mimetic technologies to Earth's life-support systems, without lapsing again into the role of manager of the planet. On the one hand, eco-mimetic technologies in the Anthropocene are natural-technological hybrids characterized by agency themselves (self-perseverance) and beyond human control. On the other hand, the earthing of technology by the incorporation of the conativity of nature in our technological design even increases the autonomy of these hybrids, and, with this, the uncertainty and unpredictability of their future developments. In the Anthropocene, human eco-mimetic agency consists in an eco-mimesis, in which natural-technological hybrids are constituted that are attuned to Earth's life-support systems, but in the awareness of the fact that the ecological conditions on which they depend do not fall under their jurisdiction and that changes and transformations of nature can suddenly withdraw its support without consulting us.

Notes

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1. This means that contrary to philosophers like Heidegger, who argued that the age of technology was characterized by the oblivion of being, we argue that the Anthropocene provides precisely an opportunity to have an experience of 'being' (Zwier and Blok 2017). This experience of the whole of being implies that human being is brought down to Earth and, second, that all our efforts to transcend earthly existence are to no avail (Morton 2013).

2. With this, we do not want to imply that Crutzen and Schwägerl had such a concept of biomimesis in mind. In fact, they did not reflect systematically on their notion of a symbiotic way of steering. In this article, we take their call for a symbiotic way of steering as an inspiration to develop a biomimetic notion of symbiotic steering. For an introduction of the philosophy of biomimicry, see Blok and Gremmen (2016). In this article, we use the terms biomimicry, biomimesis and biomimetics interchangeably. For the differentiation between these notions, see the insightful work by Dicks (2016).

3. In fact, one can argue that biomimicry as technology does not make sense if it does not strive to enhance and improve the modus operandi of nature. In this respect, we can conclude that the anthropocentric position is central in biomimetic technology. We can even argue that only the second form of *mimesis* as perfection of nature can claim to be biomimetic technology in the proper sense of the word.

4. In this respect, Baskin is right that, in the literature on the Anthropocene, the human constructedness of nature is explored, whereas the nature-constructedness of humans is neglected (Baskin 2015).

5. Parts of this section have been published already in Blok 2016.

6. In fact, Spinoza derived his concept of conativity from ancient philosophers like Lucretius and Cicero (Groome 1998, 29). Nonetheless, we call Spinoza one of the origins because he was the first philosopher to develop a full concept of conativity as a principle of nature.

7. The distinction between *living* nature and *dead* matter is already questioned as a typical *modern* distinction (Jonas 1966). According to Folz, the distinction between *phusis* (nature) and *zoe* (life) consists in the fact that *zoe* "designates a particular character of *phusis* within which self-emergence is intensified" (Folz 1995, 132). However, nature is often identified with life, or as Alfred N. Whitehead puts it: "Neither physical nature nor life can be understood unless we fuse them together as essential factors in the composition of 'really real' things whose interconnections and individual characters constitute the universe" (Whitehead cited in Folz 1995, 131). Contrary to Folz, we claim that the expansion of our concept of 'life' to include Earth's materiality provides a concrete principle of nature that can be used in biomimetic practices.

8. Whereas Peter Forbes, one of the proponents of biomimicry, argues that "what makes bio-inspiration possible is the miracle that nature's mechanisms do not

have to be ‘alive’ to work” (Forbes 2005, 5), we argue here that we have to extend the domain of the ‘living’ to the inanimate or materiality in our concept of biomimicry.

9. Although eco-mimicry or eco-mimesis would be a better name for what we have in mind here, we continue the vocabulary of biomimicry and speak of an *eco-centric* orientation of biomimicry in this article.

10. *Conatio* is a translation of the Greek *horme*, impulse or onset.

11. In this, we deviate from Spinoza’s original intuitions, which were precisely monist by nature.

12. One can argue that, as long as matter is undifferentiated, it cannot respond to anything other because, prior to difference, there is nothing other for it to respond to. Although we can argue that the traditional concept of causality is inappropriate to conceptualize the *event* of responsive conativity, the question makes clear that future research should be dedicated to this event character of responsive conativity.

References

Aristotle. 1980. *The Physics*, trans. Philip Wicksteed and Francis Cornford. Cambridge/London: Loeb Classical Library/Harvard University Press.

Baskin, Jeremy. 2015. “Paradigm Dressed as Epoch: The Ideology of the Anthropocene.” *Environmental Values* 24: 9–29. https://doi.org/10.3197/096327115X14183182353746

Bataille, Georges. 1991. *The Accursed Share*, vol. 1, trans. Robert Hurley. New York: Zone Books.

Beck, Ulrich. 1992. *Risk Society: Toward a New Modernity*. London: Sage.

Bennett, Jane. 2010. *Vibrant Matter: A Political Ecology of Things*. Durham, NC: Duke University Press.

Benyus, Janine. 2002. *Biomimicry: Innovation Inspired by Nature*. New York: Harper Perennial.

Blok, Vincent. 2015. “The Human Glance, the Experience of Environmental Distress and the ‘Affordance’ of Nature: Toward a Phenomenology of the Ecological Crisis.” *Journal of Agricultural and Environmental Ethics* 28(5): 925–38. https://doi.org/10.1007/s10806-015-9565-8

Blok, Vincent. 2016. “Biomimicry and the Materiality of Ecological Technology and Innovation: Toward a *Natural* Model of Nature.” *Environmental Philosophy* 13(2): 195–214. https://doi.org/10.5840/envirophil201692035

Blok, Vincent, and Bart Gremmen. 2016. “Ecological Innovation: Biomimicry as a New Way of Thinking and Acting Ecologically.” *Journal of Agricultural and Environmental Ethics* 29: 203–17. https://doi.org/10.1007/s10806-015-9596-1

Clark, Nigel. 2011. *Inhuman Nature: Sociable Life on a Dynamic Planet*. Los Angeles: Sage.

Crutzen, Paul J. 2002. "Geology of Mankind: The Anthropocene." *Nature* 415: 23. https://doi.org/10.1038/415023a

Crutzen, Paul J., and Carl Schwägerl. 2011. "Living in the Anthropocene: Toward a New Global Ethos." *Yale Environment 360*. http://e360.yale.edu/feature/living_in_the_anthropocene_toward_a_new_global_ethos/2363/ (January 24). Accessed April 10, 2016.

Dicks, Henry. 2016. "The Philosophy of Biomimicry." *Philosophy and Technology* 29(3): 223–43. https://doi.org/10.1007/s13347-015-0210-2

Ellis, Erle C. 2011. "A World of Our Making." *New Scientist* 210: 26–27. https://doi.org/10.1016/S0262-4079(11)61376-6

Folz, Bruce. 1995. *Inhabiting the Earth: Heidegger, Environmental Ethics, and the Metaphysics of Nature*. New York: Humanity Books.

Forbes, Peter. 2005. *The Gecko's Foot: Bio-inspiration—Engineered from Nature*. London: Fourth Estate.

Groome, Thomas H. 1998. *Sharing Faith: A Comprehensive Approach to Religious Education and Pastoral Ministry: The Way of Shared Praxis*. Eugene, OR: Wipf and Stock.

Jonas, Hans. 1966. *The Phenomenon of Life*. New York: Harper and Row.

Kauffman, Stuart A. 1993. *The Origins of Order: Self-organization and Selection in Evolution*. Oxford: Oxford University Press.

Kolbert, Elizabeth. 2011. "Enter the Anthropocene—Age of Man." *National Geographic* (March): 77.

Lacoue-Labarthe, Philippe. 1998. *Typography*. Stanford, CA: Stanford University Press.

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

Lovelock, James. 2006. *The Revenge of Gaia: Why the Earth Is Fighting Back—and How We Can Still Save Humanity*. New York: Penguin.

Mathews, Freia. 2011. "Towards a Deeper Philosophy of Biomimicry." *Organization & Environment* 24(4): 364–87. https://doi.org/10.1177/1086026611425689

Morton, Timothy. 2013. *Hyperobjects: Philosophy and Ecology after the End of the World*. Minneapolis: University of Minnesota Press.

Myers, William. 2012. *Biodesign: Nature, Science, Creativity*. London: Thames & Hudson.

Nietzsche, Friedrich. 1988. *Nachgelassene Fragmente 1884–1885*. Kritische Studienausgabe, Band 11. München: DTV/de Gruyter.

Plumwood, Val. 2002. *Environmental Culture: The Ecological Crisis of Reason*. New York: Routledge.

Sloterdijk, Peter. 2001. *Nicht Gerettet. Versuche nach Heidegger*. Frankfurt am Main: Suhrkamp.

Sloterdijk, Peter. 2009. *Du mußt dein Leben ändern. Über Anthropotechnik*. Frankfurt am Main: Suhrkamp.

Sloterdijk, Peter, and Hans-Jürgen Heinrichs. 2006. *Die Sonne und der Tod. Dialogische Untersuchungen*. Frankfurt am Main: Suhrkamp.

Spinoza, Baruch.1992. *Ethics: Treatise on the Emendation of the Intellect, and Selected Letters*, trans. S. Shirly. Indianapolis: Hackett.

Steffen, Will, Paul J. Crutzen, and John R. McNeill. 2007. "The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?" *Ambio* 36(8): 614–21. https://doi.org/10.1579/0044-7447(2007)36[614:TAAHNO]2.0.CO;2

Todd, Nancy, and John Todd. 1994. *From Eco-Cities to Living Machines: Principles of Ecological Design*. Berkeley, CA: North Atlantic Books.

Vernadsky, Vladimir. 1998. *The Biosphere:* New York: Copernicus. https://doi.org/10.1007/978-1-4612-1750-3

Winner, Langdon. 2013. "A Future for Philosophy of Technology—Yes, But On Which Planet?" Keynote lecture at SPT biannual meeting, Lisbon, Portugal.

Zalasiewicz, Jan, Mark Williams, Will Steffen, and Paul Crutzen. 2010. "The New World of the Anthropocene." *Environmental Science & Technology* 44: 2228–31. https://doi.org/10.1021/es903118j

Zwier, Jochem, and Vincent Blok. 2017. "Saving Earth: Reflections on Technology in the Anthropocene." *Techné: Research in Philosophy and Technology* 21(2 & 3).