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HISTORIOGRAPHIC ESSAY

Environing technologies: a theory of making environment

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ABSTRACT

The central proposal of this article is that *environing technologies* shape and structure the way in which nature becomes environment, and as such used, perceived and understood. The argument builds on the understanding that *environment* is the result of human intervention. *Technology* is here understood broadly as a terraforming practise, materially and conceptually. We suggest that the compound environing technologies enable us to see environmental change on multiple scales and in new registers. That technologies alter the physical world is not new; our contribution focuses on the conceptual, epistemological, economic and emotional appreciation of systems and aggregates of technologies that is part and parcel of material change. The environing technologies that enable such articulation and comprehension hold potential in the future transformation that our societies need to undergo to overcome the crisis of environment and climate.

KEYWORDS

Environing technologies; environing; environment; technology; historiography; transformations

Introduction

History requires intentionality, stated R. G. Collingwood in his posthumously published book *The Idea of History* (1946). The writing of history was therefore in his view the intellectual enterprise whereby we analyse what humans do because only humans have intentions and only humans perform *acts*. However, according to Collingwood, change also happens without human intention; variations and evolution that belong in the realm of nature are *events* that are not part of history. This binary and exclusive understanding has become enormously influential and shaped the self-understanding of generations of historians and historiography as a practice. At the same time, it has been much questioned. Some of the most vocal critique has come from environmental historians who have argued, as a central idea of the rationale of their own enterprise, that in human history nature also matters.[1] Nature may not have intentionality, but it has agency: as epidemics, as natural resources, as disaster, as climatic influence. Central in this vein is the work of Fernand Braudel where nature became a (mostly) slowly changing background factor that conditions human life, action and thought.[2] Environment was, in Braudel's language, the framing of human action, far more important than Collingwood ever allowed it to be, still less filled with agency than most later environmental historians would give to it.

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This was a perhaps modest expansion of the historiographical program. Practitioners of the posthuman turn have taken these discussions much further, lowering thresholds between bodies and other 'vibrant matter' building and surrounding humans, societies and the nature we inhabit, including animals which, the animal turn has suggested, are our kin and companion species.[3] Over several decades, these discourses have worked to destabilize some of the very categories that historiographic thinkers such as Collingwood and Braudel utilized.

However, we have now reached a moment when we must yet again return to these most foundational concepts of historiography. Nature, we might say, is no longer what it used to be, nor is environment, intentionality, agency or even history.[4] Historiography is undergoing a profound reorganization through the destabilizing and re-articulation of these very concepts. As a point of departure for this article, we propose that the emerging changes in historiographical debates and in the actual writing of global and environmental history depend on ongoing transformations of human–Earth relations. We also propose that these relations deserve further articulation and need to be theorized. Finally, we propose that historical narrative, often provided by scientists, is already a growing part of these transformations, and that professional history can play a potentially major role in articulating and qualifying the new understanding of human–Earth relationships.[5]

This emerging *Weltanschauung* is marked by the insight that human intervention in the world is no longer limited to the intentional. On the contrary, we increasingly discover that some of the most profound consequences of human actions are at the same time unintended and also comprehensive. The changes are not only multiple and additive, they acquire new properties as they scale from local levels towards the global and planetary, and in so doing destabilize the Earth system, hitherto not perceived to be a concern of history or even a historical object. Now it is both.

Many have described how human action has external impacts and that these can change 'the face of the Earth'. George Perkins Marsh examined already in the middle of the nineteenth century how the work of humans had transformed Europe and North Africa over thousands of years, and that view of the tremendous force of combined human actions has since been a staple in history, geography and related disciplines. Yet, from the standpoint of the maturing twenty-first century, it is obvious that this outlook has captured just a fraction of the impacts that humans wreak on the planet on which they live. The change Marsh observed was on the scale of landscape, and it was in large part additive. He described changes in one forest, the next forest and the forest after that, and he could see how dune sands drifted, in first Gascony, then Denmark, then Prussia. Geographies, or environments, of forests and sand dunes had changed according to fairly uniform patterns.[6] The same was true for plains, rivers and marshes. He presented changes in populations of fauna, and in species composition on land, in rivers and lakes, often the result of extinctions caused by humans. In sum, Marsh's approach represented a comprehensive and profound change. Still, it remained limited to the scale of landscape and, above all, it was not scalable. The approach rendered an environment that was created in discrete parts that formed unified categories that appeared in many places but did not affect the way the Earth as a whole functioned.[7]

For more than a century, Marsh's ideas represented the way change in nature was perceived as an effect of 'human action'. In recent decades, this idea has started to become superseded by another kind of change, proposed by practitioners of the Earth sciences.

Here, the idea is that change is now so pervasive and deep that it affects the very functions of the Earth system, a concept that originated in the 1980s.[8] This change operates in a very different way than the additive forces of human agency. The changes Marsh described were intentional, or could at least be derived from conscious efforts, although these often failed and caused harm and abuse. Earth system science evolved to suggest that whatever the marks left on the face of the Earth, *the functions* of the Earth *system* were changed in unintended and often dangerous ways. By 2009, these changes were presented as actual or potential transgressions of a set of planetary boundaries which could 'tip' the planet into an undesirable state with dire consequences for Earth and humanity.[9] These changes happened because the total impact of human action was no longer seen as just an additive process. Rather, the impact accumulated and scaled so that effects were not only spatial and physical but at the same time influenced and tweaked natural geosystemic processes.

What does this change in understanding of human impacts mean for history? The core argument of this article is that historiography could and should engage with the appreciation for the aggregate and scaling forces of human agency. The Earth itself, in its entirety, has over the course of the recent past – what has been termed the Anthropocene – become part of history. In our reading, this means that the time has come to reflect on how history can be addressed on this level and encompassing these phenomena, without losing track of the conventional usefulness of history as providing explanations and imaginaries about the humans in the world. To encompass these emerging categories of the human predicament is indeed necessary to keep history relevant. A further dimension adds to the challenge: we need to reclaim Earth system processes as part of what we as humans have responsibility for, now that we recognize the connections between human actions and Earth system properties. This reclaiming work has barely started, and we predict that it will take many avenues in the future.[10] Our contribution here is conceptual and concerns the formation of environment, which, we argue, is a far more encompassing, productive and sense-making activity than conventional understanding has it.

To do this, we suggest two fundamental concepts: environing and technology. Environing is the process through which humankind impacts nature to form environment. Technology is one of the central means through which humans exert their influence on the world. Environing, like technology, is formative both in the material and the immaterial domains. The environment is therefore not only the material world 'out there' that human activities impact on. The environment is also increasingly a word to signify the knowledge-based representation of the material world in which humans and their actions are embedded. Hence, we suggest that environing consists of processes whereby environments appear as historical products, and technologies as the tools required for the environing to take place.

To environ

'Environment' is an old idea, in the Western world having roots in Antiquity. It can be related to the idea of *climate* (*klima* in Greek, derived from *klinein*, to lean, slope), referring to geographical position in relation to the equator and the poles. With this meaning, it has been used over the centuries to explain differences between civilizations, societies and nations.[11] The common current understanding of 'environment' can be

dated to the immediate post-World War II period when the concept was presented in this new way in a set of texts by conservationists. This use of 'the environment' was a conceptual framing of the growing and largely negative consequences of human activities on the earth. 'The environment' came to be about effects on geographical, chemical, biological, ecological or other categories such as soils, waters, air, forests, marshes, plants and animals. It also referred to interior environments, in buildings and in bodies, and to relations between environment and human health.[12] This stemmed in turn from the environment as understood as a phenomenon out there with some geographical reach, pertaining to either the micro- or local level, or to more comprehensive levels, increasingly over the post-war decades including the entire Earth, the 'global environment'. The environment became an integrative concept that incorporated all of these scales, uses and particularities, and its capacity for scaling is one of the reasons for its success as a concept, now in nearly universal use. But the concept nonetheless retained a first-order understanding as something to do with spatial extension in a physical geography. 'Environmental problems' were malfunctions in human relations to this spatial, biogeochemical complex.[13]

Etymologically, however, 'environment' is not only something out there but rather, as a term, signifies human agency, although not always intentionality. The concept stems from an older form of the word: *environ*. The word was used as a preposition, an adverb, but predominantly as a verb in Early Modern texts, including in Shakespeare. One meaning of environ was to encircle or encompass, for example the household and farm.[14] But the boundary wasn't absolute. Environment also had potential for the future farm, it was part of resources and conditions. To include that which environed and so, literally or figuratively, expand the encircled area was, we might say, to 'make environment'.

If environing is regarded as a historical process, it allows us to redefine the social into also including a larger part of the 'natural environment'.[15] Invoking the environing turns the focus of environment not so much on the disturbance or destruction of it wrought by humans, but rather to a dynamic relationship with vast, sometimes threatening, but also resourceful surroundings that humans were meant to transform and could turn into an ever-changing product of their ingenuity and practice.

The modern orthodoxy of 'the environment' has been closely tied to it as a problem of change, or rates of change, for which numbers were developed, crucially, to build the modern understanding.[16] Too high rates of change in the wrong direction were connected to the risk of decay, disaster and a crisis that would encompass nature and humans alike. It became a crisis concept: the environment is where the problems with human encounters with the natural and outside world have manifested themselves, sometimes in profound and ominous ways.

Still, nobody would deny that human life on earth has also meant the creating and continued shaping of environments that have been useful, necessary, good and caring. Environment as a crisis or problem concept is not applicable to these. Clearly, there are ambiguities here. Whether an environment is good or bad, useful or undesirable, beautiful or ugly, or just nothing of the above is a matter of discussion and valuation which is in itself historical, with hegemonic views shifting over time and across cultures.[17] We will concentrate on the possibilities that may open up if we think of 'the environment' as essentially holding two very different dimensions: one linked to a set of problems and crises in the environment out there, the other linked to the human

capacity, and necessity as a species, *to form and shape surroundings to sustain the kind of life that we call human*. Our primary interest here is in this latter dimension: the *environing*, including its unintended consequences.

Technology

To environ is a process of making. We suggest that key to that making is technology. Just like the term environment, the term technology has a history which has importance for our general argument. It is derived from the Greek words *techne* and *logos* meaning the knowledge or learning of art or craft. It shows up in the English language in the seventeenth century. It was not in very wide circulation. If occurring at all in a given setting, this was also how the term was used up until the middle of the nineteenth century: as a way of describing a study of a field and a practice rather than an object in itself.

To emphasize the *making* potential of technology is congenial with naming institutions for higher technical education, such as the Massachusetts Institute of Technology in 1861. This was also the use of the term in Europe in the nineteenth century, as the knowledge of useful arts, both mechanical and fine arts, for example, in Germany, England and France. Eric Schatzberg contends that 'the current characterization of technology as the methods and material equipment of the practical arts did not exist in nineteenth-century English'.[18]

Even though MIT and other EuroAmerican schools that used it in their names made the term more popular, it was still uncommon before the twentieth century. Furthermore, it was in fact not much used by social theorists before 1900. This does not mean that the processes of industrialization were of no interest to social scientists, only that the terms invoked in that discourse were others, like *industry, machinery* and *invention*. As showed in different contexts by Leo Marx and Ruth Oldenziel, the most influential social theorist bringing 'technology' into his analytic vocabulary and into a more general discourse was Thorstein Veblen, the economist–sociologist.[19]

This process of semantic drift was built upon incorporating the meaning of the German word *Technik*, meaning primarily activities of engineering and modern industry but also more generally the practical arts, into the US term technology, thus expanding it. The present-day consequence of this move is that while many European languages have different words for the two phenomena, American English uses 'technology' for both.[20] Leo Marx has argued that the shift in the meaning of the term answered to a need to describe the emerging age, in fact filling a 'semantic void'.[21] Schatzberg also notes that this process opened the possibilities of misunderstandings and limitations, as in the case of historian Charles A. Beard who linked technology to progress.[22] All historical efforts to delimit and name particular activities (as the coinages of the word 'technology' represent) are of course indicative of vastly complex cultural conditions, and any felt need for or perceived inadequacy of a given term, as these authors invoke, would themselves require causal explanations. But we can at least with their analyses begin to detect the multiple instrumentalities that have inhered in the term 'technology'.

Environing and technology are in every historical manifestation two very different terms. The verb environ was once used but turned into a noun that later underwent a conceptual revolution and became hegemonic, whereas the verb was all but forgotten.

Technology, the noun, led a life in the background and also underwent a conceptual transformation. Although profoundly unrelated historically the two concepts have undergone similar semantic transitions. Several generations after 'environment' and 'technology' were catapulted into conceptual centrality in the early phases of radical expansion of human presence and impact on the Earth – arguably at the start of the so-called Great Acceleration at the end of World War II[23] – we can now see that they do relate closely, and in more ways than earlier conceptual discussions have revealed.

Typically, when technology has been related to environment, it has been to suggest that certain technologies create environmental problems, or in certain instances help solve such problems. This underscores the deep divide, almost a dualism, between the two concepts, further reflected in the fact that history of technology and environmental history as academic practices 'have shared a tendency to each "black box" the cores of the other specialization' as Sara Pritchard puts it.[24] We argue instead that putting them together can shed light on the practices whereby humans make environments, both by shaping material environments and by bringing into being perceived or conceptual understandings of the environment or different aspects of it. The term, 'environing technologies' brings the concepts back to the making roots of both. There are also more tangible reasons to look at technologies in this way. Technologies are linked to social practices and to human intentionality. In that sense, they link the making of environments to history and change. Technologies travel, and they can be applied on different geographical levels which means that they can bring comparability and scalability to the analysis of environmental history.[25] In fundamental ways, they are also linked to science and to changes in scientific understanding.

Environing can start in the library, the lab, the field or even in the space above Earth. During the twentieth century, we saw how what we now call 'the environment' has been articulated, and thus brought into existence in a very fundamental way, through work in a range of sciences that made the Earth and its various physical and biological manifestations into its objects of research. Indeed, one such object was the planet itself, signified by conceptual neologisms such as cryosphere (1923), biosphere (1926) and ecosphere (1958).[26] Environments on different scales became not only objects of human action, they also became objects of human knowledge, on scales ranging from the local, for example, a lake ecosystem,[27] to the global, a process which itself has a history. These new environments appear at different points in time, as separate but related entities on different scales, what Deborah Coen has called 'different slices of the phenomenal world'. This has, over time, added to the growing necessity to scale between 'slices', or environments, and hence also between different levels and technologies of acquiring knowledge.[28] Essential elements of these technologies are conceptual (new words), theoretical (new ideas of understanding) and empirical (based on new data), but even these elements require technologies, in turn, embodied in instruments, storing facilities, technologies of observation, collection, calculation and multiple others. It is important to note, however, that this is not only, or even primarily a question of the size of these technologies, nor a larger version of strongly coupled elements that are seen to make up Large Technological Systems.[29] Rather, the environing technologies that we discuss here are better considered as aggregate technologies that can be loosely or tightly coupled, assemblages of technologies and practices. Either way, environment is their product.

Types of environing technologies

We suggest that there are several types of environing technologies. We will present our argument here using a subset of three types.[30] They are *writing, sensing* and *shaping*. All these importantly comprise *both* environing through perception and understanding *and* physical changes in nature. Distinctions along this continuum are possible, but typically they are interconnected. They all require work, i.e. some kind of activity on the part of humans through which these technologies can perform their environing function. In historical analysis, they are hard to separate. Practice and understanding co-evolve and there is continuity between knowing and doing, mind and hand.[31]

Shaping is the aggregate type that can perhaps most readily be associated with environing. Among shaping technologies are for example those that restructure, move, elevate, flatten, empty and fill. Examples, each with their own history, would include technologies related to herding, forestry, irrigation, fishing or the release of carbon dioxide into the atmosphere. This is also the type of technology that played a key role in pre-industrial agriculture and the ordering and control of land close to the household or village.[32] In antiquity, we would find architectural constructions like aqueducts, dams, roads, and houses forming cities and even holding empires together. Technologies changed the world, whether in ways big or small, globally or locally, vertically or horizontally, with consequences that were far reaching in time or just temporary. The shaping of material environments can be seen as an integrative process which contains elements of conceptual work, intentionality, knowledge, or other ideas and practices. The technologies have varied across time and space but they have essentially retained this functional property of environing, regardless of their declared purpose.[33] Hence, much environing work and its outcomes are accidental rather than intentional.

The two other types of environing technologies have a capacity to also materially alter nature, directly or, more significantly, indirectly. Here, we would like to stress particularly the conceptual work they are doing. It is possible to find examples of environing technologies that clearly belong to either sensing or writing. Sensing technologies are all those that gather and register material and information about nature, through for example seeing, feeling, hearing and smelling. Aided by instruments, these activities multiply into numerous forms of environing. Walking, measuring or counting birds may be regarded as ways of making environment through *sensing*. However, often these technologies are also connected to *writing*, as documenting is intrinsic to many activities, especially those which are circulated in society and over time. The United Nations Convention on the Law of the Sea, UNCLOS, or the IPCC Fifth Assessment Report are examples of writing (documents) that environ. So are, say, novels by Margaret Atwood or Rudyard Kipling. The 1966 BBC motion picture 'Born Free' about the lioness Elsa, bucolic scenes painted by Watteau and captivating illustrations of the ozone hole are all examples of writing in the form of images.

Sensing and writing are hence often tightly coupled and commonly they work together with shaping to form a practice and a framework of interconnected activities. UNCLOS depended on previous portrayals of the open seas as contentious and not clearly defined. The ozone hole rested on years of atmospheric research using sensing technologies as well as means to put the data into interpretable images.[34] And, in much the same way, gardening mostly involves a combination of the ability to see and sense and plan and shape.

Thus, the main point we wish to make is that although a particular activity might be characterized as writing, sensing or shaping, these enactments are all for the purpose of our argument tightly connected as environing technologies. Environing as a term for physical alterations of nature is probably the most common understanding, and a very valid one, however our contribution is to also detail and highlight the processes by which conceptions are changed. Turning our eyes towards those, we find technologies that sense and sort, categorize and evaluate, calculate and project, display and illustrate, evaluate and distinguish, compare and analyse. Some of these technologies could be said to be qualitative rather than quantitative in nature and some would be hard to classify as either. In the category of conceptual environing technologies, we may also put nature painting and photography, temperature measurements, rules on how to appropriate a commons or move in a national park, economic theory applied to nature – from eco-system services to fishing quotas and estimations of uranium ore assets – and calculations of salinity changes in the oceans. The work here is often but not exclusively intellectual and reflexive.

At times, these technologies alter nature through the equipment used to measure. Buoys or thermometers are artefacts *in situ*, which then to some extent deploy nature as a laboratory. Geological assessments of ore and metals, rare or abundant, entail equipment that might be temporary and leave no long-term trace, or on the contrary leave drilling holes or excavation sites.

The dominating impact on nature from writing and sensing environing technologies lies in their co-working with shaping. Fishing quotas, in and of themselves, do not alter nature, but build on and affect our understanding of what is possible, desirable, sustainable, legal or just. When fishing quotas are observed, however, they affect fishing, which affects fish and other water-living species and non-living objects, as well as the water, the sea floor and harbours. If extended to the Large Technological System that fishing might be said to constitute, the environmental effects are comprehensive. Other activities have effects that are more modest, such as courses on how to cut apple trees or ways of deciding on the location of tourist infrastructures such as hiking trails and cabins in a nature reserve. In this category, the art of displaying the sensed environment also belongs to these technologies, since without it perceptions could not be affected.

One could say that these varieties of environing technologies concern how the senses perceive and transform impressions of and data from the world and turn them into intelligible constructs. These are deeply human, generic activities, common to many human communities, although practiced in very different ways and to varying extent. Some pursue them actively, even professionally. At the same time, we are all recipients of the results of these environing activities, suggesting that the understanding of environment is in constant flux just as the materially shaped environment is also undergoing ceaseless change. As such, in some fundamental way, all humans are environing co-producers of environment. Parts of these broader activities and sensitivities are scientifically studied in fields such as environmental psychology, environmental semiotics, and cognitive strands of biology and evolutionary theory that can help explain how and why humans pursue these activities on the evolutionary timescale.[35] Much of this research has been focused on how humans perceive the surrounding environment, in a EuroAmerican tradition from Herbert Spencer's early observation that environment was precisely that which surrounded a human being and made an impression on its mental faculties.[36]

We will use the remainder of this article to elaborate on the environing technologies of sensing and writing as they allow for and interact with shaping.

Environing technologies at work

Satellites and the distant view

Our first case will discuss a specific technological system that builds on remote sensing by satellite, in its environing capacity.

Since 1957, it has been possible to launch technology into orbit around Earth and in increasingly elaborate ways gather information about the planet through space technology. The possibility of transgressing the nation border early on resulted in international negotiations and the UN Committee on the Peaceful Uses of Outer Space was set up already in 1959. In 1967, the Outer Space Treaty came into force, stressing space as a domain of peace and to the 'benefit of all people'.[37] Most of the surveillance satellites launched have been military or for purposes mainly connected to intelligence gathering as part of national security. However, many examples of the dual use of military technology for civil purposes are to be found in space applications. This distant view, involving an enormous amount of equipment, has also presented new perspectives on the object at hand.[38]

Here, we use the example of remote sensing satellites which collect data by circling the Earth, often in near polar orbits at 700 or 800 km above the Earth's surface, or from a position in the geostationary orbit, around 36,000 km above the Earth's equator. Through different kinds of instruments, signals are picked up from the area that the satellite covers. The received signals can either be just passively emitted from Earth, like heat or light, or they can be reflections of a signal that the satellite instrument itself actively emits. The registered signals are stored in the on-board computer and are regularly downloaded to Earth stations where they can be processed. Remote sensing satellites were envisioned as early applications of space technology, both in Europe and the US, even though implementing them was not always easy.[39]

These satellites contribute to our understanding of the Earth and 'the environment' through the images produced on the basis of the collected data. Images are an important way of communicating, which, in this particular context, the first photographs of the Earth from space can illustrate.[40] Since satellite technology became abundant, these images have also been a source through which we can understand not only change but the planet itself. During the 1980s, satellite technology could discover and map natural resources and started to serve as a surveillance tool. Remote sensing imagery complemented and at times replaced traditional cartography and thus acquired a similar power in structuring our understanding of the world.[41]

In climate change science, satellites have been central. An example is the monitoring of Arctic sea-ice which has taken place with satellites since the late 1970s and allowed for a long and comparative data set. The use of satellite imagery in conveying the news of shrinking sea-ice has been a forceful way of presenting the fact that this seemingly local change is actually a global issue. Data gathered *in situ* can be projected onto a sphere thereby mimicking a planetary image or even photograph. However, satellite data used for this purpose do not only have the benefit of being calibrated for the entire

area. They also represent a view from a distance, invoking ideas of objectivity and trustworthiness. This perceived public understanding of the satellite as offering a bird's eye vantage is easily enough possible to de-construct, and we are not suggesting that there is an innate objectivity to distance. Nevertheless, it is a common trope that is repeated in the circulation of satellite imagery.[42]

A satellite mosaic consists of a number of images that are merged into larger composites that in theory can cover the entire planet. Each contributing image can be magnified and thus the scaling allows also for local community use of the sea-ice imagery. For the general public, Google Earth has become the ultimate tool that seemingly without effort allows us to shift perspective from our street view to the planetary. When first presented, this data-crunching technology caused awe among internet users, in the face of newly impressive techniques of digitalization and computer processing, at the same time as it raised issues of integrity. For some, this capacity is now so ubiquitous that the complex technology behind it has become mundane or even invisible.

This way of scaling from local to global is a forceful example of environing. The message from the remote sensing imagery is that climate change is a matter with a speed and extent that is difficult to fathom. The global perspective has a magnitude that overshadows the local view with claims that are encompassing and total. Climate change on a global scale is indeed terrifying and the sublime of global imagery might contribute to framing this issue emotionally.[43] The anxiety, or *(Um)Weltschmerz*,[44] that climate change raises is tightly coupled with the possibility of fully comprehending the consequences of change. This means that the environing capability of the forceful communication of climate change that satellite imagery can allow for also comprises an understanding through emotions of fear and horror. Photography, repeat photography, film and the fine arts are other ways of configuring climate change with the explicit ambition of affecting the audience, allowing for a deeper understanding, emotionally as much as cognitively.[45] This type of environing is essential and can serve as a bridge to what novelist Amitav Ghosh has called the 'unthinkable'. Ghosh argues that climate change has been deferred from fiction to science fiction precisely because we cannot grasp the change as real and thus we have kept it within the realms of science.[46] In other words, the case of satellite imagery suggests that environing technologies have the potential of speaking to our senses.

Creating global climate

Our second example is about a large and complex aggregate technology that has indeed created an alternative understanding of nature and the human condition. These technologies measure and calculate, model and extrapolate, using an increasing multitude of instruments and scripting practices.

When 'the environment' emerged in its new conceptual appearance after World War II, it did not encompass anthropogenic climate change. On the contrary, the idea that humans can warm the atmosphere with their emissions of carbon dioxide was not much discussed. Climate scientists and meteorologists were adamant that anthropogenic climate change had not happened, and would not happen. The state-of-the-art *Compendium of Meteorology* (1951) issued the following verdict from a leading authority on climate history:

> In the past hundred years the burning of coal has increased the amount of CO2 by a measurable amount (from 0.028 to 0.030 per cent), and Callendar [...] sees in this an explanation of the recent rise of world temperature. But during the past 7000 years there have been greater fluctuations of temperature without the intervention of man, and there seems no reason to regard the recent rise as more than a coincidence. This theory is not considered further.[47]

This does not mean to say that the idea didn't have its proponents. British steam engineer Guy Stewart Callendar had published several, much debated, but thoroughly refuted papers.[48] A parallel development was that of numerical weather prediction, with path-breaking work in Princeton, headed by John von Neumann. The project had several international collaborations and hosted guests from groups in Oslo and Stockholm.[49] The group in Stockholm, under Carl-Gustaf Rossby who served as a link between the Princeton and the Scandinavian teams, managed to produce functional 24 hour weather predictions in 1955.[50] In preparing for the International Geophysical Year 1957/58, Rossby was also in contact with Scripps Institution scientist Charles David Keeling and advised him on the decision to locate his measurement instrument in Hawaii, famously producing the curve indicating the rising level of atmospheric CO_2.[51]

This was a time of major breakthrough for the use of computers in large-scale atmospheric data management and numerical weather prediction became a template for applied computing that would soon spread across many areas of science, technology and society at large. Computing technology was also applied to the problem of climate change. Although the principles and mathematics that were needed to calculate the increased warming effect of solar radiation in the atmosphere caused by carbon dioxide were well established since the 1820s and were pursued with real numbers by the Swedish chemist Svante Arrhenius in the 1890s, it wasn't until the 1950s that man-made global climate became the subject of systematic study. It was soon aided by computers fed with growing amounts of monitoring data.[52] What emerged was a monitoring/calculating technological system, 'a vast machine' in Paul Edwards' words that produced evidence of what we may call a *global climate reality*.

The main building blocks of this machine were multiple, complex and pervasive: (a) computing facilities (in the immediate post-IGY days in the form of Data Calculation Centres, with time in government agencies, universities, research institutes, etcetera); (b) monitoring structures (weather stations around the world, sea buoys, sounding balloons, manual collection of carbon dioxide absorption data in the oceans and of course the measurement of atmospheric CO_2 levels at Mauna Loa, Hawaii and other sites); and (c) models that the scientists built with the data and the algorithms they fed their computers with. These components, technologies in their own right, worked together as a loosely coordinated aggregated technology that in essence shaped what was to become an entire dimension of the environment, namely that of anthropogenic climate change.

The sum of these co-working elements was neither intended nor imagined; it was accidental. By the early 1950s, when the old orthodoxy – that no human forcing of climate existed, or was even possible on the global scale – started to give way to our current one, no one could fully imagine the comprehensive environing technology that the nexus of computers, monitoring devices, climate models, and concerted research programs and collaborations would form.[53] There was always 'climate', in reality multiple local and regional climates. The environing technology of computerized climate science brought into being a global climate that hitherto had not existed.

Ecosystem services – a universalizing environing technology

Our third example illustrates environing where the technologies at work are of a slightly different kind than in the above examples. Calculation and evaluation are at the core of this example that merges economy with ecology in ecosystem services.

The idea that actively preserved properties of nature can be ascribed economic value dates to the nineteenth century when the first generation of nature conservationists in the United States learned that money was a convincing argument.[54] During the early decades of the twentieth century, 'the ecosystem' became a concept,[55] and had a major influence on thinking about succession, plant communities, species formation and later thinking about the environment. In the 1970s, the concept of ecosystem services was coined.[56] Its use expanded slowly but steadily and started to grow in earnest from the 1990s.[57] A seminal work was an edited book by Gretchen Daily, *Nature's Services*.[58] These services were originally conceived as the useful things that 'ecosystems' (including anything from individual organisms to entire landscapes) provide, such as pollination by bees or the cleaning of urban air by the foliage of trees. With time, the ecosystem services diversified and are now considered, for example, cultural, spiritual or historical in relation to how humans use or regard nature or its features, big or small.[59]

By the early 2000s, ecosystem services scholars and practitioners – landscape and wildlife managers, urban planners, environmental economists, conservationists and others – had formed several projects and also an international organization to promote and spread the use of ecosystem services as a comprehensive approach to be applied in nature conservation, land use planning and similar practices. The Economics of Ecosystems and Biodiversity initiative (TEEB) was hosted by the United Nations Environment Programme (UNEP),[60] and has played a role in organizing the various actors and the components of ecosystem services research and thinking into a functional whole, including the publication of brochures, research findings and 'Manuals' for the operational use of ecosystem services principles and practices. Central for many of those who developed the ecosystem services approach was to offer a more compelling argument for preservation than the protection of individual species or particular places for their beauty, uniqueness, charismatic properties or other values, an ambition that underpinned the *Nature's Services* book.[61] Economic value in the form of ecosystem services would come with numbers that could not be so easily disputed as such presumably subjective claims. Furthermore, the numbers would be founded on ecosystem *science*, that purportedly could determine the significance of a particular species or eco-system, and hence services would be different both from values, held by anyone, and from simple preferences, expressed by consumers in a market place.

The concept of ecosystem services, taken as an integrated whole, comprising concepts, models and methods, can be seen as a technology whereby *values* in nature are identified, articulated and quantified using particular modes of calculation. The methods are typically fetched from conventional economics. An often-cited example is health effects of urban trees, the benefits of which can be calculated.[62] Scenic green areas that provide the backdrop in movies and TV serials are 'worth' the turnover generated by those industries.[63] Already in 1997, a later much cited study calculated the value of all ecosystem services of the entire Earth and found that number to be much higher than the total value of the world economy,[64] a number that made economists doubt it on formal grounds as disturbingly large whereas others doubted it based on common sense as ridiculously low.

One can regard the universalizing economic methods of the last 30 years as technologies of globalization,[65] creating a quasi-universality of action, and of values, in parts of the world and domains of societies where previously hard-to-compare diversity and local particularism reigned.[66] These can be meaningfully called technologies precisely because they offer certain prescribed routines, techniques and practices whereby the standardization and the ensuing comparability is purportedly achieved. That achievement in turn opens up the possibility to move issues and dilemmas, for example of controversial urban planning, from the mess of local claims and into the clarity of numbers; that is, from the sphere of politics to that of science (or quasi-science). What is most interesting to us in this context, however, is how it as a technology has proven capable of introducing an entire category of the environment into scientific and policy discourse. Before the 1990s, the economic value of nature was not calculated, and certainly not in this way. Now it is. The economic language of numbers in combination with the methodological toolbox of TEEB's Manuals has provided an off-the-shelf technology with which to literally produce these kinds of 'services' and hence add a category to 'the environment'.

Assessing climate and environmental change

Our final example is close to the previous in that it evaluates and assesses the environment in a specific way, thereby construing it. This assessing is, however, not primarily of economic nature.

Since the 1970s, assessments have become more and more common as a way of establishing a *negotiated version* of the state of the art in science on a particular topic.[67] Within the environmental realm, the influence of these exercises has varied, partly due to the outcome of the negotiation process, and partly since the efforts to meet the consequences of the assessments are vastly different.[68] To address the ozone hole, once established, was different from the tasks that come out of the conclusions from the IPCC, to take two extreme examples. In the case of climate in the Arctic, the region itself was co-constructed and reinterpreted with the assessments and the consequences were not only an appreciation of this region as one where climate played a disproportionately important role, but also an articulation of indigenous knowledge in the process.[69]

The objectives of assessments vary, and the understanding of the term itself has also undergone change.[70] To assess something originally meant evaluating some kind of performance or process. However, in present day parlance, environmental assessments typically refer to a monitoring exercise, aimed at collecting and collating data. Through a systematic process of inquiry and synthesis, such exercises use the data to present a comprehensive state-of-the-art description of environmental conditions, underpinning policy recommendations. The scientific teams involved in these practices have grown and are typically broad and international, indicating that the stakeholders might also be rather large and consist of multiple communities, typically with conflicting interests. This mission drift, from collecting to also evaluating and advising, is further increased by the genre that *assessment reports* comprise. They are published as scientific reports but are regularly accompanied by so-called executive summaries or summaries for policymakers. Increasingly the conclusions take the form of short video sequences or other kinds of multi-modal communication, illustrating what media scholars have termed communication convergence.[71]

The executive summaries, presumably the part of these publications that are mostly read, thus hold a specific position in framing the conclusions of an assessment and thereby function as an environing technology. Through the vast amount of data, specific conclusions are highlighted and form a hegemonic understanding of what should be considered important aspects. Furthermore, for the assessments to work as policy instruments, the reports need to go from being solely descriptive to being also prescriptive. However, for the assessment summary to maintain its non-political aura, suggestions need to be carefully formulated. In an analysis of assessments carried out in the framework of the Arctic Monitoring and Assessment Programme, it was shown that a sliding language managed to move from the main purpose of the assessment, namely to map the cryosphere, to making suggestions and proposals on indigenous people's societies and 'resilience'.[72] At the same time, in the executive summaries of the assessments, agency was placed mainly on external drivers, primarily climate change, marginalizing regional, national and local politics. However, to talk about climate change in scientific terms could also have political implications. The use of a terminology that incorporates the language of *external drivers* is in fact a framing that obscures human action.[73] In both cases, the assessment reports structure our understanding of the environment and thus are a case of an environing technology.

Making environments – discussion on practices

The sections above present examples of what we can term environing technologies at work. Their characteristics are that they are complex sets of operations, methods and instruments (technologies) that perform a category of work (environing) in defining 'the environment' as a way of understanding human–nature relations and as a domain of policy and social action. It is evident from the examples that this work is not necessarily performed intentionally by the actors who are involved in it. They do not set out to use technologies of shaping or sensing in a deliberate effort to environ, i.e. create dimensions of the environment. Properties of the environment are added as an unintended outcome of their work, pursued for other purposes. This is an important point to make because it underscores that the environment, seen as having been produced in this way, can be usefully regarded as an *integrative social concept*, growing from human action, rather than as just a word for something out there that serves as a carrier of problems for societies caused by societies.

What is it that environing technologies do when they environ? As the examples demonstrate, environing can be decomposed into practices that are to some degree present in all the cases reported, as well as in similar areas which we have taken an interest in but for reasons of space not presented in this paper. These comprise, for example, quota systems for fishing, boundary thinking as a property of planetary stability, such as the planetary boundaries concept linked to earth system science, or detection of acid rain and assessment of its consequences. These practices do not necessarily follow a specific time sequence, but can be parallel and iterative.

One such practice is the *assembling of data that signal (rates of) environmental change*. This is a work of *identification of aspects*, hitherto often hidden or poorly articulated, of the environment. Another such practice includes *work of articulation and definition* which also encompasses conceptual development. *Concepts are invented* in order to capture the particular environmental phenomenon or feature, the 'global

warming', the 'ecosystem services', the 'planetary boundaries'. Sometimes these concepts are developed early, sometimes ex post. Much work is also put into *quantification to establish a category, object or number around which consensus can be built*, for communication or policy, like 2 degrees, or 350 parts per million.[74] In fact, quantification and calculation are the very cornerstones on which comparison can be achieved and thus often hold a specific position that enables environing on many scales. Hence, the environing technology is composed by a set of related practices, observation, monitoring or other means of data gathering and processing, and their specific instruments, or technologies (satellites, models, computers), increasingly purpose-built. As we have seen, the technologies also include *elements of visualization and other means of effective presentation to summarize, simplify and convince*.

Practices like these have been articulated and treated before in the areas of science and technology studies, history of science or history of technology but under different names and with different concepts (for example in Actor Network Theory). They are less common in environmental history, where the questions asked have been different and linked more to the *problem* of environment than to the *making* of environment, although important exceptions exist.[75] There is a growing literature on histories of technologies and artefacts that have 'enabled' the production of environmental knowledge, focusing on the often very concrete and material assembling of data in the field, which can be on land, in soils, in water, on animals or in urban settings, buildings, roads and other infrastructures. Pursuing this analysis of technologies joining with nature, some historians have been able to identify hybrid 'envirotechnical regimes'.[76]

This is also a *process of translation* – from observation, data and knowledge to *environmental usability*. The environing technology offers something that goes beyond scientific knowledge in the elementary sense; it is aggregated knowledge often presented in a narrative form with some historical depth (since it is about change). It connects knowledge with compelling concepts, relevant challenges and tools for social organization and action in society, industry or otherwise. The technology facilitates this element of social action as it also offers a strong *potential of circulation* – of data, aggregated understanding and policy recommendations, although of course that circulation will encounter friction and its outcomes may often be contested, as for example in the case of ecosystem services. The work performed by the environing technology can be seen in the light of Foucault's concept of governmentality, developed around 1980.[77] The environing technology is what makes nature governable through the work of assembling, identifying, monitoring, articulating, quantifying, conceptualizing and visualizing; through to the search for policy instruments with which to apply the environing technology to *governance*. When this stage is reached, the technology has performed the environing work with a high level of impact.

It is important to see that this is not only a matter of describing some aspect of the world in a new way, as all new knowledge does to a smaller or bigger extent change the world. The crucial thing here is that the environing technology augments the environment, adds new dimensions, hitherto unseen or, if seen, not established enough to serve as legitimate parts of the environment. By looking at environing technologies in this way, we will be able to reconstruct the history of the environment and the history of technology in new ways, including of course exploring the intimate relations between these two strands of history. But we will also be able to look forward and consider the role of technologies, as here understood, in the future work of transformations and

transitions needed to deal with the increasingly complex human–Earth relationship. In that sense, environing technologies can themselves be shaped and chosen and take on political properties.

Historicizing the human–earth relationship

There are good reasons to draw attention to environing – a concept of agency, largely forgotten and not used much under the hegemony of environment as predominantly a crisis concept. These reasons relate to the power and the potential of the concept of technologies and their common links to the current global predicament. The human–Earth relationship is indeed in a grave condition, and we lack a historical narrative for it. There is a growing consensus that a major transformation of how societies relate to nature is necessary, a transformation which is currently undergoing articulation.[78] This transformation will have to be characterized by a reduced global ecological footprint of humanity, and for humanity to stay within some version of the boundaries of the Earth system. It will entail a reformed relationship between human societies and the planet as well as changed relationships between and within societies.

This great transformation of the twenty-first century is typically presented as a phenomenon on a scale that defies any simple definition, let alone any single solution. It is rather conceived of as plural, pervasive and bringing mutually reinforcing waves of change, not unlike what Karl Polanyi captured with his concept and book, *The Great Transformation* (1944): a broad, integrative societal upheaval that was wrought by the growth of the capitalist system and industrialism alongside the modern state.[79] Everything changed, from production technologies to energy use to human habits and habitats to values, virtues and ideas of good and bad and what was a meaningful and rightful life to lead. A coming transformation, arising amidst those conditions Polanyi identified, may be as great, or even grander simply because of the global connectivities and the sheer size of humanity and its extent and imprint on the planet.

Technologies will play a large part in this transformation, just as they did in the one Polanyi described, or even earlier. The idea is in a certain sense simple: we need transformative technologies that can do for modern societies and on a global, integrative scale what technologies did in pre-modern, indeed pre-prehistoric times to expand and secure human livelihoods. However, there is also a risk of simplistic reliance on technology that can derive from dehistoricized understandings. After all, if new technologies don't work in the direction of responsible change and are not part of, or supporting the kind of innovation that is required, there is little chance that the desired change will come, and the human–earth relationship will remain dangerously unsustainable.[80] In envisioning the narrative for a future major transformation, it may therefore be useful to think about environing technologies as a framing concept.

The cases we have presented all show an analytical capacity helpful in understanding the coming transformation. One can agree or disagree with the desirability, or the directionality, of the transformation that they may underpin. For example, while it is easy to see benevolent outcomes of the formation of the idea of a global climate and its anthropogenic change – as foundational for the effort to mitigate and adapt – we might be less convinced that the formation of technologies of valuation of ecosystem properties, or of environmental assessments are as worthwhile in their current manifestations.

Environing technologies are different and may be more or less useful, but the take-home message is that they exist as an emerging historical category.

Ultimately, this speaks to the importance of historicizing the human–Earth relationship – needless to say a grand effort, but not one entirely unheard of.[81] We need a history for the unintentional human environing of the Earth into the crisis-ridden physical world we live in. Our contemporary societies are restlessly seeking better knowledge of how the Earth works and how human societies can change to take care of it better. In some way, humans have always known this, on smaller scales. What is new to our time is the magnitude of the human–Earth challenge, and the necessity of a history that can manage scale. To assist in that work, we need framing concepts and narratives that can help us get out of unproductive conventions or lock-ins to see more clearly the relationship of technologies and environment. This article attempts an embryo version of such a narrative.

Notes

1. Worster, "Appendix: Doing Environmental History," esp. 292–93.
2. Braudel, *La Méditerranée*.
3. Bennett, *Vibrant Matter*; and Alaimo, *Bodily Natures*.
4. Jørgensen, Jørgensen and Pritchard, *New Natures*; and Purdy, *After Nature*.
5. Good examples of scientists as narrators of the new *Weltanschauung* are Flannery, *The Future Eaters*; Zalasiewicz, *The Earth After Us*; Smil, *The Earth's Biosphere*; and Kolbert, *The Sixth Extinction*.
6. Marsh, *Man and Nature*, ch. 3 "The Woods," 419–21 (sand dunes); Lowenthal, *The Past is a Foreign Country*; and Lowenthal, *Quest for the Unity of Knowledge*.
7. There is however, at the very end of Marsh's book, a passage where he opens the possibility of accumulating effects that might indeed impact not just on the Earth as a whole but even on the planetary scale and on other celestial bodies. It is prophetic, but also hypothetical and far from 'systemic', Marsh, 465.
8. Mooney, "Evolution of Natural and Social Science Interactions."
9. Rockström et al., "A Safe Operating Space for Humanity" including the "Planetary Boundaries Diagram" with its striking visual representation of the idea; Steffen et al., "Planetary Boundaries"; and Morseletto, "Analysing the influence of visualisations," 44–45.
10. See however Chakrabarty, "The Climate of History" for an attempt to address some of these dimensions.
11. Glacken, *Traces on the Rhodian Shore*.
12. Warde and Sörlin, "Expertise for the Future"; and Warde, Robin, and Sörlin, *The Environment*.
13. Sörlin, "Environment."
14. Nardizzi, "Environ," 185–89; Warde, "The Environmental History"; and Warde, "The Environment."
15. Sörlin and Warde, "Making the Environment Historical," 8.
16. Porter, *Trust in Numbers*; and Warde, Robin, and Sörlin, *The Environment*.
17. From the vast literature, e.g. Nicolson, *Mountain Gloom and Mountain Glory*; Glacken, *Traces on the Rhodian Shore*; Passmore, *Man's Responsibility for Nature*; Callicott, "The Land Aesthetic "; Soper, *What Is Nature?*; and Casey, *The Fate of Place*.
18. Schatzberg, "Technik," 490–91.
19. Marx, "Technology"; Oldenziel, *Making Technology Masculine*.
20. See note 18 above.
21. Marx, "Technology," 564.
22. Schatzberg, "Technik," 488.
23. Steffen et al., "The Trajectory of the Anthropocene."

24. Pritchard, "Toward an Environmental History," 229.
25. White, "The Nationalization of Nature"; and Aslanian et al., "How Size Matters."
26. Vernadsky, *Biosfera*; Dobrowolski, *Historia naturalna lodu*; Barry, "A. B. Dobrowolski"; Cole, "The Ecosphere"; and Höhler, "Ecospheres."
27. For example, Raymond Lindeman's Cedar Bog Lake in Minnesota in the 1930s. Lindeman, "Experimental Simulation of Winter."
28. Coen, "Big Is a Thing of the Past," 312.
29. Hughes, *Networks of Power*.
30. We draw on a typology that has its roots in a research agenda that Sörlin crafted when we together founded the KTH Environmental Humanities Laboratory in 2011. https://www.kth.se/en/abe/inst/philhist/historia/ehl/about-the-ehl/research. The work to find and shape the KTH EHL over its first couple of years of existence also involved several of our then colleagues in the Division of History of Science, Technology and Environment at KTH. The concept, environing technologies, has been applied in research at the Division, but this is the first time we make an effort to elaborate it theoretically.
31. See the contributions in Roberts, Shaffer, and Dear, *The Mindful Hand*.
32. Warde, "The Environmental History."
33. This whole shaping function of technology is a central theme of Lewis Mumford's influential *Technics and Civilization*, although Mumford talks about this process as a "conquest of the environment", using "environment" in the old style as a neutral holder of space, underscoring the separation of technology from environment rather than its role in the creation of environment. Mumford, *Technics and Civilization*, 154.
34. Parson, *Protecting the Ozone Layer*.
35. De Young, "Environmental Psychology Overview"; and Lang and Kull, *Estonian Approaches to Culture Theory*.
36. Spencer, *The Principles of Psychology*, 194; Warde, "The Environment"; and Warde, Robin, and Sörlin, *The Environment*, 30.
37. UNITED NATIONS. "UN Treaty on Principles."
38. Grevsmühl, "Serendipitous Outcomes in Space History."
39. Mack, *Viewing the Earth*; and Wormbs and Källstrand, *A Short History of Swedish Space Activities*.
40. Jasanoff, "Image and Imagination;" Cosgrove, "Contested Global Visions;" Cosgrove, *Apollo's Eye*; and Poole, *Earthrise*.
41. Gärdebo, ongoing dissertation work.
42. Wormbs, "Eyes on the Ice"; Daston and Galison, *Objectivity*.
43. Wormbs, "Sublime Satellite Imagery."
44. Cf closing conference on the Marie Curie ITN on Environmental Humanities, (Um) Weltschmerz, Munich, October 2018 (http://enhanceitn.eu/umweltschmerz-announcing-final-enhance-event/).
45. Cf James Balog and his film "Chasing Ice."
46. Ghosh, *The Great Derangement*.
47. Brooks, "Geological and Historical Aspects," 1016.
48. Callendar, "Air Temperature;" Callendar, "Can CO2 Influence Climate?;" Callendar, "The Artificial Production;" Callendar, "The Composition of the Atmosphere;" Fleming, *The Callendar Effect*; and Sörlin, "The Global Warming that Did Not Happen."
49. Harper, *Weather by the Numbers*.
50. Persson, "Early Operational Numerical Weather prediction."
51. Bohn, "Carl-Gustaf Rossby's Collection"; Bohn, "Concentrating on CO2"; and Fleming, *Inventing Atmospheric Science*.
52. Edwards, *A Vast Machine*.
53. Bolin, *A History of the Science and Politics of Climate Change*.
54. Barrow, *Nature's Ghosts*.
55. Tansley, "The Use and Abuse"; and Willis, "The Ecosystem."
56. Westman, "How Much Are Nature's Services Worth?".

57. Norgaard, "Ecosystem Services."
58. Daily, *Nature's Services*.
59. TEEB, *Manual for Cities*; TEEB, *The Economics of Ecosystems*.
60. Ring, "Challenges in Framing."
61. See note 58 above.
62. Bolund and Hunhammar, "Ecosystem Services in Urban."
63. de Wit et al., "Investing in Natural Assets."
64. Costanza et al., "The Value."
65. Ernstson and Sörlin, "Ecosystem Services."
66. See Mitchell, *Carbon Democracy* for a similar argument. See also Mackenzie on how models and metaphors work performatively to shape and not just portray the economy, e.g. MacKenzie, *Material Markets*.
67. Oppenheimer, *The Practices of Scientific Assessment*.
68. Mitchell et al., *Global Environmental Assessments*.
69. Nilsson, *A Changing Arctic Climate*; Krupnik, *SIKU: Knowing Our Ice*; and Hastrup, "The Icy Breath."
70. Wormbs and Sörlin, "Arctic Futures."
71. Schneider and Nocke, *Image Politics of Climate Change*; and Jenkins, *Convergence Culture*.
72. Wormbs, "The Assessed Arctic."
73. See note 70 above.
74. Whitney and Kiechle, "Introduction."
75. We will only mention two here. First, William Cronon's concept 'second nature', referring to man-made nature which in his analysis of *Nature's Metropolis: Chicago and the Great West*, 1991, was melded together with 'first nature' largely via the workings of the capitalist market. Second, we would like to mention Stephen Pyne's for us very inspirational, constructively constructivist, *How the Canyon became Grand*, 1998, in which Pyne brings out the wide range of cultural, scientific and political practices that led, first, to the conceptualization of the Grand Canyon, second to its elevation as a national park and monument and ultimately to a global phenomenon and attraction.
76. A few examples: Fiege, *Irrigated Eden*; Rozwadowski, *Fathoming the Ocean*; Pritchard, *Confluence*; Benson, *Wired Wilderness*; Murphy, *Sick Building Syndrome*. An excellent overview of these trends in recent environmental history is Pritchard, "Toward an Environmental History of Technology," 244.
77. Foucault, "Governmentality."
78. Schot, "Confronting the Second Deep Transition"; and Schot and Kanger, "Deep Transitions."
79. Polanyi, *The Great Transformation*.
80. Stirling, "Direction, Distribution, Diversity!"; and Scoones, Leach and Newell, *Politics of Green Transformations*.
81. See e.g. Christian, *Maps of Time*; Höhler, *Spaceship Earth*; Höhler, "Local Disruption or Global Condition?"; Jasanoff, "Image and Imagination"; Thomas, "History and Biology in the Anthropocene"; Sörlin and Warde, "Making the Environment Historical"; Bonneuil and Fressoz, *The Shock of the Anthropocene*; Sörlin and Lane, "Historicizing Climate Change"; and Warde, Robin, and Sörlin, *The Environment*.

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