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Beyond Innovation and Use, or Why We Must Follow Technologies through Time

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Abstract: Synthesizing various studies that follow technology beyond innovation and use, this article aims to continue widening the scope of history of technology toward this perspective. It argues that we must follow technology through time and—in addition to its use—its maintenance and repair, while also addressing its so-called afterlife, encompassing topics such as reuse, reconfiguration and/or restoration, decline or deliberate ruination, abandonment, and removal and/or remains. Recent studies of these issues underscore that the temporality of technology does not end with the end of its use, suggesting instead multilayered temporalities. History of technology is thus challenged to rethink some of its established and largely unquestioned approaches, such as the "innovation timeline", the model of "technology diffusion and substitution", and "lifecycle" metaphors borrowed from twentieth-century theories of economic growth and innovation.

Keywords: history of technology; temporalities; technology in use; repair; maintenance; waste; recycling; dismantling; decline; exnovation; afterlife; legacies

1. Introduction

For a long time, research on the history of technology mainly focused on "making technology". Since the 1980s, however, the social construction of technology (SCOT) and other approaches have pivotally realigned the discipline, widening its perspective from how technologies have been invented and made to how they have been embedded and appropriated in sociocultural micro contexts. The field has since developed a nuanced awareness of the heterogeneous dynamics of socio-technological change, its regional diversity, and its unpredictability. Making and using technology differ depending on economies and their wealth, as well as politics, culture, gender, and so on, and the ongoing coshaping of society and technology is producing sociotechnical changes—sometimes rapid, sometimes gradual—along with mostly unforeseen technological developments. Parallel to SCOT, environmental history has made the discipline more aware of unintended ecological problems that followed once technologies such as the car or the computer were adopted on a mass scale (Ensmenger 2018; McCarthy 2007). One of the most favorite current approaches, the "multilevel perspective", thus aims to interweave macro-, meso-, and micro levels to grasp the complexity of socio-technological transitions (Sovacool and Hess 2017).

In particular, over the last four decades, the fields of user and gender studies have underlined that users have not only "appropriated" and "domesticated" past technologies but also coshaped technology's development—in daily use practices, the invention of unforeseen uses, and creative tinkering (Oldenziel and Hård 2013; Oudshoorn and Pinch 2004; Kline 2000). By retooling the technologies at hand, users have even become inventors. David Edgerton's call for a focus on "technology-in-use" has illustrated that, around the globe, everyday life has been and continues to be dominated less by adapting the latest innovations to local contexts and daily routines than by using and modifying long-established technologies such as water supply, sewage systems, pens, or bicycles (Edgerton 1999, 2006). In parallel, studies on failure or malfunction, accidents or blackouts, and repair and maintenance have underlined that

"using" itself cannot be taken as a given as either a concept or a practice (Weber et al. 2023; Denis and Pontille 2022; Bernasconi et al. 2022; Krebs and Weber 2021; Henke and Sims 2020; Russell and Vinsel 2018; Reith and Stöger 2012; Graham 2010; Nye 2010; Conway 2004; Bauer 2006; Perrow 1999). Technologies fail or break down. Moreover, wear and tear and creeping decay mean they require care over time, a fact that the Western "innovation delusion" has largely obscured (Russell and Vinsel 2020).

Such studies more carefully trace the paths of past technologies beyond their innovation and (first) use, while others in emerging subfields such as environmental studies, repair and waste studies, or transition studies have taken the first tentative steps beyond this moment, that is to say, beyond innovation and (re)use towards the often obscure "after-use" phase that sets in once the initial use of artifacts and technologies is discontinued. Recently tackled topics include reuse and related issues; the rendering of technologies "obsolescent"; deliberate decommissioning, dismantling, and removal; unwanted or enforced decline; abandonment and falling into oblivion; and, crucially, technology's critical persistence beyond its use. Incidentally, all of these topics challenge the traditional tools, methods, or sources employed by historians as none of them leaves behind any easily accessible documentation or sources.

The following chapter aims to further widen the scope of the history of technology in this direction. It pulls together various research strands, both traditional and novel, from the history of technology and "envirotech" history and from the emerging body of studies that follow technology beyond innovation and use. Time and the timescales of technology thereby become fundamental in novel ways as we have to question timelines traditionally employed within the history of technology—among them, the "innovation timeline" (Edgerton 2006, pp. 28–51), the "technology diffusion and substitution" model, and the "cradle to grave" lifecycle metaphor borrowed from twentieth-century theories on economic growth and innovation.

The chapter thus concludes with a critical reflection on the intersection of time and technology, not least since our present is characterized by troublesome temporal challenges, many of which are related to the ways in which past technology reaches into the future or is in need of repair or restoration. These include the diagnosis that we live in the Anthropocene yet also encompass intensifying fights for justice in a changing climate—across the globe and between generations—that call for urgent transitions in post-fossil societies.

2. "Broken World Thinking": Repair and Maintenance

Practices of reusing, mending, and reworking represent core issues for preindustrial or non-Western technologies and have commonly been identified as formal and informal activities in economies of makeshiftness and scarcity (Stöger 2019; Reith 2003). Though these issues did not entirely fade away in rich regions, mass consumer societies did reframe them during the twentieth century as secondary activities, i.e., as subordinate to mass production or the building of technological systems. Narratives of Western "modern" technological development have largely obscured them: economic statistics are often scarce or nonexistent when it comes to the number of employees in the sector of repair, maintenance, and secondhand technology or the economic value of these services and markets.

Ever since Stephen Graham and Nigel Thrift reevaluated inspection, maintenance, and repair as the "engine room of modern economies and societies" (Graham and Thrift 2007), several studies have demonstrated their relevance for keeping infrastructures, producer goods, or consumer technologies running or adapting them to new requirements. While studies on the Global South highlight the importance of informal markets, bricolage, and workarounds, those on the Global North have sketched the ups and downs of professional repair markets for twentieth-century consumer goods in more detail, thereby refuting the idea of a decline of repair in affluent societies. In the case of American mass motorization, Kevin Borg has framed this field as "technology's middle ground" (Borg 2007, p. 2). Operating between technology use and technology production, repair and servicing have been a basic prerequisite for the spread of new appliances—from domestic water and

electricity connections to the automobile, the television set, or the cell phone (Borg 2007; Krebs and Weber 2021; Zumbrägel 2023; Nova and Bloch 2020). Maintenance and repair, along with the reconfiguration of existing and novel elements, stabilize infrastructures and keep them up-to-date.

New technologies have not only given rise to new fields of repair but also to practices—often highly gendered—of self-repair and creative tinkering, such as do-it-yourself radios, car tuning, or computer modding and retrofitting (Takahashi 2000). People do their own repairs not only for economic reasons or in emergencies (for example, in the event of a breakdown), but also for the fun of technical work and skills, to preserve or pass on technology, or to reuse it for other purposes (Voges 2017). With the domestic toolbox and sewing box, gendered repair cultures are still omnipresent in today's material culture despite the decline in repaired household goods, measured against the increase in the number of things owned (Derwanz 2023; Voges 2023).

Studies of repair and maintenance have shifted the focus from new to already appropriated, "old" technologies. They have thereby also underlined the fragility and vulnerability inherent in any technology. Steve Jackson has called for "broken world thinking" that takes "erosion, breakdown, and decay, rather than novelty, growth, and progress" as starting points for studies of technology (Jackson 2014, p. 221). Such a perspective has been supported by diverse ethnographic research on the Global South (Anand et al. 2018; Anand 2017). But, many Western regions, too, experienced the challenge of rapidly deteriorating infrastructures and the splintering of urban networks from the 1980s onwards because of insufficient maintenance or rehabilitation and a phase of neoliberal privatization (Graham and Marvin 2001; Choate and Walter 1983). Moreover, most twentieth-century infrastructures were built with a certain time frame and frequency of use in mind, requiring restoration after several decades of operation, often under conditions differing from those that were planned. Highways and bridges built in the postwar economic boom, for instance, had to cope with an unpredictable increase in loads from heavy goods vehicles for which they were not converted in time, resulting in dilapidated street infrastructure.

Lee Vinsel and Andrew L. Russell, instigators of the "Maintainers Network", have recently noted a serious malfunctioning of the American economy induced by the short-termism of current economic thinking. They argue that economic actors and society at large have lost sight of long-term concerns, such as providing drinking water through solid infrastructures, and are driven rather by an obsession for "disruptive innovations" and the "next big thing" (Russell and Vinsel 2020).

3. From Cradle to Grave? (Re)use, Repair, and Removal

By stabilizing technology's time in use, the activities of repair and maintenance are deeply interwoven with temporal concerns. Mass production and mass consumption have introduced new ways of producing, designing, distributing, and consuming technology, all of which have been studied in great detail. But they have likewise generated and shaped new notions of temporality with respect to technology, such as the "innovation cycle" theory or the idea of a quantifiable "lifespan" of technology. While studies on the history of technology frequently apply terms and concepts such as innovation cycle, lifecycle, and obsolescence, we lack a nuanced historical analysis of their origins in innovation theories and marketing, of their circulation and appropriation in production and engineering, and of their relation to reuse and repair, substitution, and removal.

Cyrus Mody has demystified "Moore's Law": for decades, this principle has insisted on short innovation cycles for digital equipment and declaring it to be obsolete after less than two years in use. Yet this "law" is no naturally given law but a social construct fulfilled only through the mass sale of laptops and cell phones and the profit to be earned by such rapid turnover (Mody 2017). These ever-tighter cycles of innovation have caused significant problems for repair and maintenance and favored removal. The reproach of "planned obsolescence" has given rise to critical discourse, but we still lack historical studies on how engineering developed and applied methods to standardize lifespans and durabilities that

have become the backbone of all kinds of innovations, from light bulbs to bridges and nuclear plants (Weber 2018, 2021; Krajewski 2014; Slade 2006).

Following technology through time and beyond (first) use helps us historize and deconstruct these concepts as "chronotechnologies" developed in business and marketing (Nowotny 1989) in order to impose novel time rhythms on users, economies, and societies alike. It also allows us to see the many instances in which users have defied, subverted, or counteracted this time regime. In his book The Shock of the Old, David Edgerton describes how poor people, especially in the Global South, appropriate, rework, and reconfigure "old" technologies, often imported from elsewhere, to suit their needs. With practices described as "modding" or "creolization", users or craftspeople creatively combine elements of old and new and of imported and locally available technology to adapt imported cell phones, bicycles, buses, trucks, or cars to regional needs (Beck 2009; Edgerton 2007). But, thrifty rearrangements and, notably, secondhand markets have also helped Western consumers, in particular those of little means, to acquire cars, washing machines, or consumer electronics.

Such cascades of reusing, handing down, reselling, or retrading between first, second, or even further uses have also been described for preindustrial or socialist economies, though we still lack such studies on capitalist mass consumer societies. The example of cars suggests that secondhand markets were part and parcel of these objects' diffusion and circulation. Like those of repair, the supplies and scope of secondhand markets have transformed over time and moved beyond local networks to encompass global perspectives. Moreover, cultures of repair and reuse are deeply interwoven with facilities for dismantling and disposal, a relationship that remains understudied in the field of repair (Weber and Krebs 2021): whether a technology is repaired for further use or left broken and thus taken out of service depends on regimes of production and consumption, available repair infrastructures, and dominant waste practices and systems.

Following technology through time and beyond use also means scrutinizing what happens after use; it means questioning concepts such as the end-of-life stage of technology and its substitution. While economic history and the history of technology have described larger socioeconomic processes of structural transformation, the decline of technological sectors, and regional deindustrialization, it is only recently that technology's destabilization and decline have themselves attracted historical attention, guided by the presumption that this stage might be decisive for the current challenge of decarbonizing economies by phasing out and "exnovating" the fossil-based technologies of the past (Zahar et al. 2023).

Many technological artifacts limp along to their demise, and even infrastructures or buildings from the industrial past have often vanished gradually, leaving behind what Anna Storm has called "post-industrial landscape scars" (Storm 2014). Examples of technologies left to deterioration include industrial ruins as well as old cassette recorders or mobile phones kept in domestic basements or drawers. Other technologies have been intentionally dismantled, destroyed, or removed, while some rare specimens are preserved as cultural heritage, be it by museums and similar institutions or by private hobbyists, and become the object of conservation and restoration practices meant to slow down their further decay and wear.

If we understand "making technology" or "appropriating technology" as meaningful processes that require time, work, and energy in addition to knowledge, the same holds true for the inverse, the "unmaking" of technology through dismantling, demolition, disposal, or recycling (Weber 2014). These practices require deliberate action and involve reassigning value and meaning in, for example, declaring a technical artifact to be outdated and surrendering it to deterioration—a dimension of technology that has been hardly studied so far. On the level of users, phasing out technological artifacts or discarding them seems to happen silently and without leaving many traces, compared to the acquisition of one's first car or computer, which is often linked to biographical memories.

Studies on scrap recycling and car shredding in the United States or on the more recent global business of ship dismantling and electronic waste disposal have described the diverse actors, practices, and waste streams—often transsectoral and far-reaching—involved in what is

mostly dirty and obscure waste work (Lepawsky 2018; Salehabadi 2016; Zimring 2005, 2011). Waste and recycling economies emerged alongside the production and use of new technologies, materials, and products in those cases where profits could be generated by recovering marketable by-products and wastes. Tin cans from the early twentieth-century food industry were recycled by the iron industry or by synthetic fiber producers in need of tin; postwar household appliances, cars, and early mainframes were scrapped for metals; and PET bottles are increasingly in demand from today's textile industry (Denton and Weber 2021). Such recovery or "recycling" processes have not eliminated waste nor stopped the trend of increasing extractivism and waste amounts, even if the visionary idea of closing material cycles following the principle of "cradle-to-cradle" has motivated many recycling innovations.

Moreover, in cases where marketability is lacking, discarding more often than not has translated into waste disposal or ruination. As Joel Tarr and others have shown, the idea of a "natural dilution" or "purification" by natural agents in the air, soil, or bodies of water long dominated the handling of industrial pollution, from emissions to effluents and other industrial wastes. Until around 1980, waste management and engineering, for instance, propagated the notion of the "ultimate sink" as a technological fix that would eternally contain wastes and seclude them from the environment (Tarr 1996). In the end, however, in many cases, the resulting "removal" of wastes created toxic landscapes in need of remediation.

Waste studies suggest that the dirty work of removal—from dismantling to recycling and discarding—has by and large lagged behind the standards established in production and consumption; it has involved informal work, rudimentary disposal and dismantling technologies, unsanitary health risks, and hazards that have become increasingly toxic. Rich countries have furthermore begun to outsource waste and waste work, along with its risks, to poorer regions through both legal and illegal measures, thereby imposing a new kind of "toxic" colonialism (Gille and Lepawsky 2022). Concurrently, since the late twentieth century, Western Europe has promoted "green" recycling as a means of ecological waste disposal while also circumventing a dearth of regional waste sinks (Jørgensen 2019).

4. Technology's Unintended "Afterlife": Legacies, Remediation, and Aftercare

Studies in environmental history on pollution and contamination have illustrated that ecological long-term effects of technologies are not a recent phenomenon (Hughes 2014; Penna 2010; Reuss and Cutcliffe 2010; Burke and Pomeranz 2009; McNeill 2001). Even in antiquity, people recognized the environmental damage wrought by ore mining, smelting, or deforestation. While the environmental problems triggered by industrialization involved intense water and air pollution, the ecological effects of industrialized societies have expanded in spatial and temporal scales over the last 200 years. François Jarrige and Thomas le Roux thus see contaminants as "constituent elements of modernity" (Jarrige and Le Roux 2020). Recent debates about the Anthropocene have identified humans as a geological factor defined by certain technologies that have left behind irreversible markers on the earth, such as the increasing CO_2 content of the atmosphere, the radionuclides in sediments stemming from atomic weapon tests of the 1950s and 1960s, or the global dispersion of microplastics. The technosphere framework conceived by the geoscientist Peter Haff and others even suggests that the weight of human-made materials by now exceeds that of the earth's biomass.

From the late twentieth century onwards, many societies perceived the remains of their production and consumption activities as not only an ecological but also a material, technical, and cultural challenge. The "great acceleration" from the 1950s onwards has unleashed an ever-greater rate of resource extraction from the earth (Engelke and McNeill 2014) and, as a flip side, of residuals in need of disposal, from industrial waste to plastic packaging or carbon emissions. Moreover, ever-rising consumption standards in affluent societies have meant that the share of stuff, objects, and technologies being repaired, reused, or recycled rather than discarded has substantially declined over time.

Following technology through time thus suggests that the real "shock of the old" might have less to do with "old" technologies staying in use than with their persistence beyond use. Outdated technologies neither disappear nor die by themselves, and even their active substitution or removal does not completely "undo" them (Weber 2022). As Weber and Krebs have recently argued, technologies are persistent in manifold ways (Krebs and Weber 2021). One example is how path dependencies had European motorways follow routings originating in ancient Roman times or how digital interfaces carry on the QWERTY keyboard design of mechanical typewriters. Another is how infrastructures often incorporate technologies from a different age. Though largely forgotten, the computer programming language COBOL, which formed the basis of the computerization of banks, public authorities, and companies between the 1960s and 1980s, is still present in the deep structure of today's software, while the floppy disk, though long declared "obsolete", remains indispensable in avionics, medical equipment, or embroidery businesses (Hilkmann and Walskaa 2022, p. 88). Media studies and archeologists have even diagnosed a "deep time" of media infrastructure (Mattern 2015).

Technologies might also have an "afterlife" in the form of problematic legacies. This potentially hazardous side of technology's persistence has been studied by studies of pollution and contamination, situated at the intersection of the history of technology, environmental history, and STS. Metaphors such as "legacies" and "afterlife" have by now become common tropes for pointing towards potential long-term effects that the use of materials or technological interventions might leave behind, but both are loaded terms. The term "legacy" gained currency in engineering: specifically, in the field of so-called environmental remediation, as practiced since the 1970s with the promise to "clean-up" and remove contaminants through engineering interventions; "afterlife" can also be found in scholarship on historical time, where it points to the presence of objects and technologies beyond originally envisaged lifecycles.

David Nye and Sarah Elkind have moreover coined the term "anti-landscape" to refer to spaces that have become uninhabitable over time due to technological interventions such as extracting and refining coal, copper, or uranium, inducing desertification, erosion, deforestation, pollution, or contamination (Nye 2021; Nye and Elkind 2014). Multiple "ghost towns" across the United States, the Soviet Union, Scandinavia, and elsewhere left behind from the extraction of minerals, oil, and other resources pose troublesome questions about how these sites might be left to ruin or what restoration measures might be taken, industrial scars as part of cultural heritage and local identity, and the possible "re-economization" of such areas (Avango and Rosqvist 2021). Coining the term "toxic commons", Simone Müller has argued that toxicity and pollution concern us all in ways that go beyond nuclear landscapes, superfund sites, and other notorious examples of contaminated regions such as the Mississippi River's "Cancer Alley" (Müller 2021, 2023; see also Davies 2022). Scott Frickel and others have underlined that hazardous sites from past industrial activities have often been lost from historical records and local knowledge bases, leaving civic environmental activism a fundamental role to play in uncovering this past (Frickel and Elliott 2018).

For pesticides or other toxicants such as endocrine disruptors, Soraya Boudia, Nathalie Jas, Nancy Langston, and others have shown how risk assessment, regulation, and legislation are entangled with the making and unmaking of knowledge, ignorance, and regimes of (im)perceptibility, involving actors from science, policy, and industry as well as civil society (Boudia and Jas 2014; Langston 2010). Drawing on such research, Soraya Boudia et al. have recently focused on "residues" as a means to "rethink chemical environments" and the environmental impacts of chemical production, use, disposal, and regulation. They propose "residual materialism" as a framework to grasp the socio-material properties of residual chemicals that are persistent, defy control, and, more often than not, remain actively hidden away. "The past is always with us", they argue, as "our chemically saturated lives" and their residues prove to be irreversible (Boudia et al. 2021, pp. 17, 23).

The challenges at stake are succinctly illustrated by examples in which technologies or substances have been deliberately "removed" in those parts of the world where they have been declared as toxic or otherwise harmful (Armitage 2019; van Horssen 2018; Murphy 2017; Mart 2015; Davis 2014; Höper 2008). Asbestos, PCBs (polychlorinated biphenyls), and CFCs (chlorofluorocarbons), for instance, were introduced as "wonder substances". They promised to serve as reliable fire retardants or to provide insulation or efficient cooling; asbestos was widely used in construction, while PCBs paved the way for widespread electrification, as did CFCs for cooling, before all were eventually recognized as hazardous materials for which substitutes must be found. The politically driven, deliberate process of substituting new materials for these hazardous substances remained difficult and regionally fragmented, as historians have shown for CFCs or DDT, and they yielded unintended consequences, some unforeseeable and others ignored. Sweeping, disruptive policies of replacing these substances were avoided in favor of more moderate efforts, and the interim replacements of CFCs and the organophosphate pesticides that substituted DDT also came with their own problems.

The cumulative phasing out of nuclear power plants, whether because of age or political disapproval, together with the nuclear landscapes created and left behind by the atomic age have stimulated a boom in nuclear history and a new field—nuclear cultural heritage studies (Ross 2023; Bensaude-Vincent et al. 2022; Kasperski and Storm 2020; Brown 2013; Hecht 2012). The challenges of "nuclearity", as well as other long-term toxic legacies, have made researchers more aware of the temporal dimensions at stake and helped them differentiate various timescales. According to Bernadette Bensaude-Vincent, "living in a nuclear world requires a radical revision of time" since the temporality of "atomic traces and scars" "far exceeds ours" (Bensaude-Vincent 2022, p. 275). In a similar vein, Simone Müller and others speak of "toxic timescapes" to explore what they describe as "rhizomatic ways" in which contaminants permeate time, space, and bodies (Müller and Nielsen 2022).

At the same time, the undesired consequences of past technologies have had, and still have, an impact on engineering and innovation. This includes detecting and monitoring equipment; environmental engineering; methods of remediation and restoration for landfills, mine tailings, and otherwise contaminated sites, soils, and sediments; current geo-engineering or carbon-capture approaches; and any postclosure "aftercare" management. So-called postmining, for instance, involves recultivating attempts on former mining sites, geomonitoring, and groundwater management, as well as continuous drainage. In addition, quite a few innovations of the recent past have served to correct unintended consequences of previous technologies, from catalyzers or safety belts in cars to the current retroactive insulation of buildings. Some among them even amount to reviving once-abandoned technical interventions and lost knowledge, as in the case of biogas technologies, phosphate recycling in sewage treatment, or plastics produced from biomass (Weber 2019; Moss 2017).

5. Conclusions: Technology's Multilayered Temporalities

Following technologies through time and beyond their use allows us to perceive how they have been repaired, reused, decommissioned, and, possibly, substituted, removed, or ruined, as well as their potential afterlife. Topics such as technology's decline, abandonment, or removal need to become relevant themes in their own right within the history of technology. Work conditions for repair or removal have differed substantially from those of production. Increasingly situated in poor regions distant from production and first use, repair, dismantling, and waste were characterized by informal markets, cheap labor, low-tech methods, and improvisation, as well as health and environmental hazards.

Even more importantly, studying these issues in detail means challenging some of the discipline's established and largely unquestioned approaches for understanding technology's development, from innovation to use, "maturity", and decline. Technologies do not naturally follow such a linear chronology. This common narrative moreover obscures aspects of removal, in addition to residues, while excluding reinvention, restoration, reme-

diation, or heritization. Practices of innovating, using, repairing, reusing, and rearranging; of substituting, removing, dismantling; or—as examined in more recent scholarship—of "aftercare" are entangled and interrelated. While the common juxtaposition of "old" and "new" technologies suggests linear sequence or even replacement, technologies in fact often overlap.

Within the humanities, considerable thought is currently being directed towards the subject of time and temporality, even more so as the debates on the Anthropocene force us to integrate deep time into our historiographical narratives (Chakrabarty 2021; Edelstein et al. 2020). Until recently, most historians and sociologists had defined acceleration, flexibilization, or time–space compression as technosignatures of the twentieth and twenty-first centuries. Following technology through time, however, suggests different narratives and a heterochronic understanding of technology.

Technology's long-term, unknown, or unknowable environmental effects stand at odds with the often short-term horizon of economic and political decision making (Adam 1998), and even average consumers find themselves confronted with timescales that stretch the limits of human experience. Using plastic or nuclear power, for instance, brings together the deep history of oil reserves and uranium with an unknown future in which microplastics and radioactive waste will still be present. Examining the uranium ore extracted in a Gabon mine for France's nuclear plants, Gabriele Hecht has recently argued the need for entirely new narratives and analytic modes to capture the complex "interscalar" connections of time and space at stake (Hecht 2018). In a similar vein, Andreas Malm has observed that we find ourselves in an era of "diachronicity" in which climate change constitutes "a messy mix-up of time scales" (Malm 2016, p. 8). The temporality of technology does not end with the end of its use, even if this is commonly suggested by terms such as technology's "lifespan" or "obsolescence" and the "removal" or "recycling" stage of current "lifecycle" models.

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