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INTRODUCTION

Infrastructuring Environments

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New Environments, New Challenges?

Since the 1960s, the notion of a singular global environmental crisis has been popularized through the efforts of scientists, environmental activists, and the global news media. A succession of environmental issues has arisen on political agendas worldwide, from nuclear power in the 1970s to ozone depletion in the 1980s, and onto the global risks of deforestation, biodiversity loss, and climate change since the 1990s. *The* global environment, in short, has come to be constituted as a novel ontological kind, an object of massive scientific attention, transnational political contestation, and a focal point for emerging legal–ethical ideals of globalism (Jasanoff, 2003; Miller, 2007). Organized around United Nations agencies, international non-governmental organizations (NGOs), and epistemic communities of eco-professionals, the post-World War II era has thus witnessed the rise of what looks like an integrated world environmental regime (see Haas, 1992; Meyer *et al*., 1997).

In the natural sciences, too, the global environment is often performed as *one*. In a recent version, this happens for instance through the notion of 'the anthropocene', a geological age, in which humans have affected and altered the natural environment in profound and irreversible ways. The era of the anthropocene is on the verge of official recognition, spurred not least by concerns with anthropogenic global warming. As the anthropocene captures the attention not only of

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geologists, but also of social scientists and philosophers, the boundary between humans and non-humans, culture and nature, is becoming increasingly blurred. Likewise, boundaries between scientific disciplines are being renegotiated, as 'vibrant matter' becomes imbued with politics (Bennett, 2010), and as the cultural sciences have to deal with a 'more-than-human' world (Lorimer, 2012; see also the review essay in this special issue by Swanson, 2016).

However ethically troublesome, this recent call to attend to a natural environment that is never just natural, but always already also socially and culturally shaped, sits well with constructivist strands of thinking in science and technology studies (STS). At the same time, however, ideas of an integrated global environment—as implied by the notion of anthropocene, and earlier on by concepts such as Beck's (1998) world risk society—hinge on ways of thinking that enjoys an uneasy relationship, at best, with the interest in subtle processes of situated change to which much STS research is committed. Performing the global environment as *one*, in these and related ways, may well have proven effective in gaining political attention around matters of pollution, nuclear waste, and, more recently, climate change. At the same time, however, such concepts are also statements about the contested composition of the world in which we find ourselves. They do politics, while hiding most of their own economies of scale. Disappearing from sight, in particular, are the more mundane details of how the global environment gets conjured up, and (sometimes) held in place, via large-scale investments in scientific and other knowledge infrastructures (cf. Bowker, 2000; Jasanoff, 2001; Yearley, 2009).

Infrastructuring Practices

In this special issue we seek to move away from notions of an overarching environmental regime and adjacent ideas of epochal change. Instead, we bring into view the activities, materialities, and concepts through which an environment is performed in always situated and contested ways. As will be clear, moving away from a fixed global perspective brings into view an array of *environments*, themselves heterogeneous and differently organized. Throughout the contributions to this special issue, a main tenet is that 'the environment' changes shape and multiplies, especially as we look more closely at variable material infrastructures and situated practices of infrastructure making. As a consequence, our STS conceptual apparatus needs fine-tuning, paying careful attention to empirical details across a range of divergent contexts. However, in doing so, the contributors also leverage their case studies for purposes of analytical innovation, so that theoretical concepts are turned into propositions inviting further scrutiny and experimentation (cf. Stengers, 2000; Latour, 2004).

For bringing this multiplicity into focus and inviting analytical experimentation, our main analytical lens is infrastructures—or rather the modes and effects of *infrastructuring*. In common parlance, infrastructure used to be a military term

designating 'fixed facilities'; it was (and sometimes still is) seen as the *underlying basis* on top of (or through) which a society or an organization operates (Edwards 2003, pp. 186–187, quoting the *American Heritage Dictionary*). As STS analysts such as Paul Edwards (2003) have shown, vast technological systems such as roads, water supplies, power grids, telephones, and buildings work as infrastructures to the extent that they have become the naturalized background of modernity. Extending this line of argument, Bowker and Star (1999), in particular, have shown that information technologies become infrastructures through processes of system building, network extension, and standardization. What needs our ethnographic attention, Star (1999) argues, are those relational settings in which otherwise invisible infrastructures become visible, not infrastructures per se, but the practices, materials, and settings of infrastructuring.

Overall, we hope in this special issue to open up a space for discussing and reflecting on emerging relations between infrastructures and the environment, attentive to the many world-making efforts played out at their conjuncture. When juxtaposed, these two concepts suggest an interest in the way human societies *organize* their relations with the non-human (natural and technical) environment, in terms of relatively enduring patterns that stretch considerable spatial and temporal reaches. In this context, the term infrastructure still evokes, but also reaches beyond, those vast collections of material equipment with which human societies have for centuries augmented (some would say 'destroyed') their natural surroundings (buildings, rail tracks, bridges, ports, electricity cables, and so on). Drawing on Bowker and Star's contribution, in turn, we extend our notion of infrastructure to include all the technologies and organizations—of sensors, databases, research stations, protocols, accountability systems, and so on—which enable scientists, policy-makers, environmentalists, and citizens to *know* their resultant natural (or rather techno-natural) environments in specific ways, sometimes helping to stabilize particular orderings, sometimes opening up to contestation and change.

As will be demonstrated throughout the contributions, infrastructuring environments thus implies attending to activities of organizing, managing, and knowing heterogeneous relations, at once natural and cultural, material and social, and scientific and political. These aspects of infrastructuring are intricately connected, serving as an important argument for attending to situated realities rather than epochal change, and to theoretical work as the work of proposing new layers and articulations rather than a work of settling once and for all beyond any dispute. As objects of study, infrastructures are material *and* elusive all at once. As a conceptual tool, infrastructuring suggests a lens for bringing together a number of heterogeneous elements. Thus, attending to how environments get infrastructured means attending to contested landscapes of technology, knowledge, processes, and effects. It involves attending to how 'the environment' is managed and known, through what material and conceptual means, and to what effects.

This introduction first locates the special issue in a specific collaborative environment, drawing together particular geographies of STS and anthropological knowledge-making. Doing so serves also as a first introduction to the five contributions that make up the issue. We then expand on our analytical framework for thinking about infrastructures and infrastructuring, before addressing some shared methodological challenges in studying the infrastructuring of environments. Having thus outlined what we take to be core themes and discussions, we end by briefly sketching how each contribution to the special issue allows us to ask novel questions within this shared research agenda.

Emerging Trading Zones: STS, Anthropology, and Environments

As set forth in this special issue, the 'infrastructuring environments' research agenda emerges from collaborative efforts, sparked by a cross-disciplinary interest in issues of STS, anthropology, and environmental social research. Briefly recounting this history, we believe, will help situate what follows in its relevant geographical, intellectual, and political contexts.

In 2010, a group of Japanese anthropologists based primarily at Osaka University began working on what, later on, was to become the *Environmental Infrastructures* research network initiative, teaming up in the process with a group of Danish STS researchers.[1] Certain key concerns were at the heart of this effort. For one, the tenured academics in the Osaka group felt that building stronger international research collaboration was becoming increasingly important in the Japanese context, especially for young scholars. Working particularly within the diverse realms of actor-network theory (ANT), this group is committed to the idea that STS may help pose timely challenges to social anthropology, in Japan and beyond, inspiring new forms and foci of mobile, regional ethnographies. How might STS and ANT inspire and diffract Japanese (and non-Japanese) social anthropology to reflect on its interests and boundaries? (see Mohácsi and Morita, 2013). By 2012, this emerging network was granted funds from the prestigious Japanese Society for the Promotion of Science (JSPS), allowing collaborative efforts to intensify.

Apart from enrolling an interest in 'internationalization' amongst Japanese research officers, the network shares the ambition that working across STS and social anthropology, as well as across Japanese (East Asian) and Danish (European) settings, may help bring techno-scientific places and knowledge practices into view that have not previously been sufficiently attended to by either field. An element of situated learning is at work: scholars in the network who commit primarily to STS have learned about the use and standardization of technology in Inuit communities, and about indigenous taxonomy and classification practices in northeast India, to mention some encounters. Conversely, scholars in the network who commit primarily to social anthropology have learned about innovation practices in marine renewable energy, and about eco-home technologies

and the making of participatory publics in Denmark. In short, this is a network committed to exploring possible 'trading zones' (Galison, 1997) between STS and social anthropology.

A third set of shared commitments, as should be clear, is the focused theoretical and analytical exploration of contemporary environmental issues. The precariousness of environmental relations was very urgently felt in Japan in the first year of the *Environmental Infrastructures* network, when the triple disaster of '3.11', that is, the combined impacts of earthquake, tsunamis, and nuclear power plant meltdown in Fukushima and the wider North-Western region, shocked the world. If anything, this dramatic event made abundantly clear that natural disasters are always also social, technological, and political, both in their origins and in their effects. In the wake of the disaster, issues of infrastructuring are now prime concerns of Japanese politics. This is evinced, for instance, in contested processes of material reconstruction, such as those analyzed by Kimura in his contribution to this special issue. It is evinced, also, in civic efforts to rebuild radiation information infrastructures deemed trustworthy by citizens who had all but lost their faith in official forms of governmental and industry expertise (Morita *et al*., 2013).

This special issue builds upon the collaborative activities of the Japanese–Danish network; concretely, the contributions here by Morita, Kimura, and by Schick and Winthereik (all 2016) have all grown from ongoing discussions in this setting. At the same time, the special issue opens up to wider conversations. These extended conversations were enabled, importantly, by a panel dedicated to *Environmental Infrastructures* during the 4S conference in Copenhagen in 2012, bringing in a wider set of colleagues working across the boundaries of STS and social anthropology. Further, a call for papers was circulated in the build-up to this publication. Each of the scholars thus mobilized—manifested in the contributions by Asdal and Hobæk (2016) and Richardson (2016, in this issue)—brought in additional geographical sites, theoretical commitments, and analytical descriptions of infrastructuring practices. The resulting special issue covers a diverse set of case studies, building on ethnographic work across Ukraine, Norway, Denmark, Japan, and Thailand. In addition, we have made space for three shorter review essays, respectively addressing recently published academic work and an artistic intervention, all of which speak directly to and contribute new perspectives on the topic of infrastructuring environments.

In order to highlight the active work involved in the construction and maintenance of any infrastructure, the contributors to this special issue all revolve around and reflect upon the notion and process of infrastructuring. More strongly than the noun (infrastructure), this verbal form draws attention to those contested practices and projects whereby human groups seek to organize their environment via technical, material, and knowledge interventions. Yet, environments should not be seen as passive 'receivers' of such infrastructuring attempts, just as infrastructures should not be conceived as mere tools of human intentionality. Environments and infrastructures, we hope to show, each exert their own world-making effects,

working with—and against—human designs. Infrastructures include and exclude, and they enable certain kinds of knowledge and action rather than others (as highlighted, e.g., in the contribution by Asdal and Hobæk, 2016). Infrastructuring work may be expressive of human attempts to exercise control over unruly environments, but often comes with unexpected outcomes (e.g. the contribution by Richardson, 2016). At the same time, infrastructuring an environment is also a way in which human societies are made vulnerable. As infrastructures themselves become part of an environment, partially brought under control by means of yet more infrastructures, they sometimes reach the limit of their own performance (e.g. the contribution by Morita, 2016, this issue).

This special issue highlights the often-overlooked work of infrastructuring as crucial to how cultural and ethical tensions are embedded, played out, and (possibly) resolved in practice. Analyses link STS work on large-scale material and information infrastructures (e.g. Hughes 1989; Star and Ruhleder, 1996; Star, 1999; Bowker *et al*., 2010) with studies on environmental politics (e.g. Yearley, 1996; Jasanoff, 2001; Miller, 2007). Beyond standard notions of a unified global environment, infrastructuring work is organized in complex, layered, and only partially coherent nature-cultures, interlinking ecologies, material equipment, classifications, standards, expert organizations, and concerned social groups. Such an expansive notion of the social, organizational, and ethical–political aspects of infrastructuring environments draws together, and extends, conceptual resources stemming from recent work in a number of overlapping research domains, including STS, sociology, anthropology, human geography, organizational studies, and human ecology, to name only those domains most immediately relevant to the contributions that follow (see also Larkin, 2013 for a recent survey of increased anthropological attention to infrastructures).

Further, as infrastructuring environments hybridize and multiply what counts as society and nature, this composite term speaks to core concerns of interdisciplinary studies and endeavors. Having both positioned themselves squarely at the nature–culture boundary, environmental concerns in the fields of anthropology and STS, we contend, will prove central to this research agenda. In this sense, the specific network from which this special issue grows—that of the *Environmental Infrastructures* project and its affiliations—should be located within a more expansive trading zone. Here researchers in STS, anthropology, and beyond exchange conceptual tools and ethnographic sensitivities towards emerging more-than-human worlds and their 'multispecies living' (e.g. Choy *et al*., 2009; Braun and Whatmore, 2010; de la Cadena, 2012; Raffles, 2011; Law and Lien, 2013).

Theoretical Hinterland: STS on Infrastructures

Given that many aspects of infrastructure can seem 'singularly unexciting' (Star, 1999), it is perhaps unsurprising that the growing body of social studies on how humans organize their environmental relations have underestimated their

importance. Other dimensions of the current ecological predicament have received more attention, whether in terms of the international political economy of environmental destruction (e.g. Urry, 2010); the changing social perceptions of environmental risk (e.g. Beck, 1998); the rising importance of environmental NGOs (e.g. Jamison, 2001); or the various bodily encounters with nature(s) found in contemporary Euro-American everyday life (e.g. Macnaghten, 2003).

In studies on science–politics relations in the environmental domain, infrastructures show up in passing, but they seldom receive sustained attention (but see Bowker, 2000). Conversely, with some notable exceptions in urban studies (e.g. Swyngedouw, 2006; Monstadt, 2009), research on the social dimensions of material infrastructures has tended to by-pass the environmental problematic. Research on infrastructuring environments, then, needs to build some new intellectual bridges of its own (no pun intended).

In place of the master narrative of a singular global environment, gestured at in the introduction of this paper, a focus on infrastructures' performative effects invites us to take seriously the 'hetero-praxial' ecologies that interlink practices according to regional divergence, local constraints, and conflicting beliefs (Star, 1999, 384f). While environmental science overflows with utopian commitments to totalizing viewpoints, aided by earth-spanning satellites, global computer models, and other powerful technologies of vision, working infrastructures always have to be constructed from the ground up, step by step, taking local contingencies into account (Haraway, 1988). They are negotiated through friction; they break down and need maintenance; they rely on socially learnt conventions and they leave parts of the landscape unnamed, unnoticed, and unvalued.

In this sense, ways of acting towards, knowing about, and valuing the natural environment are inextricably bound up with the technical, social, and organizational practices of large-scale computer-enabled information infrastructures. Take the case of endangered species, from invertebrates to marine mammals. At the core of global concerns over declines in biodiversity stand certain authoritative databases used to assess the conservation status of plants and animals, such as the famous International Union for the Conservation of Nature (IUCN) Red List of Threatened Species. Based on a vast and complex data architecture organized around taxonomy, geographic distribution, and ecological habitats, the Red List classifies species according to a seven-point scale, going from 'least concern' over 'vulnerable' to 'critically endangered' and—as the logical end point—'extinct'. Embedded in this publicly accessible information infrastructure is the work of thousands of experts, coming from a large number of different scientific disciplines, and based in universities, museums, and NGOs around the world. Sorting out what has been counted and described, why, by whom, and to what effects raises interesting and difficult questions for STS to address (Bowker, 2000).

Growing concerns with biodiversity, in short, have proved an important site for STS scholars to explore one key dimension of infrastructuring environments: the construction and maintenance of scientific cyber-infrastructures, in the shape of

databases, archives, and other digital information systems (see Bowker, 2000, 2005; Hine, 2006; Waterton, 2010; Millerand *et al.*, 2012). Biodiversity, these studies show, is not simply a data-intensive science; it is also a domain marked by heterogeneous data-handling practices, partially incoherent archival procedures, and embedded value tensions. The biodiversity databases being developed today do not impose one hegemonic solution. Rather, at the level of data-processing practices, they unfurl within them any number of tensions. To give one famous illustration: since scientists are more likely to get funded for working on 'charismatic' animals such as pandas, tigers, and elephants, biodiversity databases face serious non-naming and non-counting problems, particularly in biological groups of invertebrates, fungi, and microorganisms, where taxonomic work is decidedly un-charismatic and low-status (Bowker, 2000). Inquiring into the making and effects of such data-deficient species would be a clear case of an infrastructuring environments study.

Issues of classification tie closely into two further epistemic issues, both at the core of nature governance and key aspects of infrastructuring environments: that is, issues of technical standard-setting and statistical quantification. Given that knowledge of most environmental issues rely on highly technical forms of analysis, what standards to apply for the appropriate generation, verification, and accounting of data often turn out to be a highly contentious problem. In part, this problematic mirrors wider issues of statistical quantification, itself a major component in various modern bureaucratic infrastructures that have come to render particular social spaces, and not least economic relations, legible and hence governable (see Rose and Miller, 1992). In environmental terms, such issues have been particularly visible in the domain of international climate change science and politics, where seemingly technical questions of where to draw the boundary between 'natural' and 'anthropogenic' greenhouse gas emissions; how to construct national directories of carbon sinks; and how to measure the 'additional' character of emission reductions from carbon trade projects have all been embroiled in prolonged controversy (see Lohmann, 2005; Miller, 2005, 2007). What this demonstrates is that, in relation to specific infrastructuring practices, issues of standard-setting relate in a direct way to questions of accountability. Environmental accountability, as the etymology suggests, is partly a question of *what* to count—and, hence, about what *counts* in specific settings (Asdal, 2008; see also the contribution by Asdal and Hobæk, 2016, in this issue).

Finally, when scanning some of the theoretical and analytical inspirations for dealing with and conceptualizing infrastructures in STS, anthropology, and cultural studies, it is important to note how, with the rise of environmentalism, otherwise taken-for-granted material infrastructures—of electricity, water supply, housing, transportation, and waste disposal—are themselves being articulated as matters of (un)sustainability concern. Such articulation work attaches to a wide variety of sites and scales where large socio-technical systems have taken root,

ranging from domestic energy appliances as sources of global climate change (Shove, 2003; Marres, 2008) over to concerns with sustainably redesigning entire networked infrastructures in the world's urban centers (Monstadt, 2009; Tyfield and Urry, 2009; Sassen, 2010). Work of sustainable redesign involves more than just material transformation; rather, it works within heterogeneous infrastructures of technical equipment, digital databases, standards, organizations, and social groups of engineers, architects, investors, urban planners, and civic associations. Importantly, moreover, such ways of infrastructuring environments often involve an explicit engagement with issues of 'green' technological innovation—for instance around renewable energy technologies—in ways that engage various concerned publics in novel ways (Rubio and Fogué, 2013; see also Schick and Winthereik, 2016, in this issue).

As we have alluded to above, the formerly 'fixed facilities' of infrastructures are widely perceived to have become less fixed and more fluid in recent years, both in their material instantiations and in their symbolic presence. This has to do, among other things, with the fact that infrastructures are increasingly used for the production, distribution, and sharing of information. Sociologist Castells (1997) famously conceptualized modern infrastructure as a 'space of flows'. His work on the network society broke new ground by emphasizing the networked character of digital communication, arguing that information can now be divided into packets and thus distributed in a non-linear fashion (see also Ruppert *et al*., 2013). Similarly, as Brian Larkin remarks in his recent review article (2013), infrastructures by definition are 'built networks that facilitate the flow of goods, people, or ideas and allow for their exchange over space'.

But even if infrastructures are becoming more fluid and networked, this does not mean that anything can connect with anything else, seamlessly. Socio-political and cultural values and practices affect how they work. A well-designed system need not lead to efficient information exchange (Jensen and Winthereik, 2013). Also, the metaphor of information or knowledge as liquid that flows freely in any direction in the digital age itself has several limitations (Moser and Law, 2006). For one thing, information generally does not flow quite so freely as the theories and theorists of a digital age, or a network society, would like to have it. Here as elsewhere, it is important to heed the point famously made in STS by Star and Bowker, to the effect that infrastructures are both physical objects and knowledge objects—and that, in both capacities, they need work of coordination and maintenance in order to function properly (Bowker and Star, 1999).

While none of the contributions to this special issue narrate their intellectual territory quite the way we have done here, they all engage actively with key aspects of this theoretical hinterland of STS engagement with infrastructures. As such, they also serve, individually and collectively, to push this engagement in novel directions—towards attention, for instance, to how layered landscape infrastructures emerge and change in long-term processes (e.g. Morita, 2016); how their obduracy is forged and contested in material politics (e.g. Richardson, 2016);

and how processes of infrastructuring rely on the work of aligning particular visions and visibilities (e.g. Kimura, 2016, this issue). In making these analytical claims, all contributions likewise engage a set of difficult methodological issues, to which we now turn.

Methods for Studying the Work of Infrastructuring

One important theme permeating work on the social and organizational dimensions of infrastructure is that, because infrastructures are embedded within or sunk inside other social and technical arrangements, they tend to be taken-for-granted, forgotten, and remain invisible (Bowker and Star, 1999). This relative invisibility prevails not simply in social science work on domains like the environment, as argued in the previous section. It feeds primarily on widespread beliefs among the relevant communities of practitioners, such as biodiversity scientists, for whom issues of digital data-handling techniques, for instance, will tend to be seen as mundane, unexciting, and low-status. Infrastructural design and maintenance are permeated by significant amounts of hidden work, work that goes unnoticed or is not formally recognized within organizational settings (Star, 1999, 385f). This is certainly true, for instance, with the work of cleaners and janitors in technological production settings; the work of secretaries in research centers; or the work of nurses in maintaining medical records (Timmermans *et al*., 1998). It may pertain as well to the work of coders and software designers in the world of environmental science and politics. Studying how environments come to be infrastructured thus requires methods for surfacing and foregrounding such hidden work.

Commenting on this conundrum, Bowker (1995) offers the apt metaphor of infrastructural inversion: studying the work of infrastructuring, he notes, involves a gestalt switch with which to wager an analytical 'struggle against the tendency of infrastructure to disappear (except when breaking down)' (Bowker and Star, 1999, p. 34). Infrastructural inversion, then, 'means learning to look closely at technologies and arrangements that, by design and by habit, tend to fade into the woodwork' (Bowker and Star, 1999; see also Star, 2002 and Jensen, 2008, p. 364). The importance of such learning again extends beyond issues of social science method, in that it pertains to entire mythologies circulating in domains of information- and knowledge-intensive work. For instance, whereas it is widely assumed that advances in medical science caused the rise in life expectancy during the nineteenth century, performing an infrastructural inversion will show that changes in living conditions, tied in particular to improved diet and sewage, were at least as important (Bowker, 1995, p. 235). Only by disregarding such practical and mundane changes in infrastructure does medical science emerge as the glorious cause of success.

To complicate the story, however, engaging in infrastructural inversion on the part of the analyst may *both* imply making mundane ecological practices visible

and being attentive to how this is already happening all 'by itself', as an event in the world. This point follows from the inherently *relational* character of infrastructures. Hence, from an infrastructural inversion perspective, acknowledging how 'one person's infrastructure is another's brick wall, or in some cases, one person's brick wall is another's object of demolition' (Star, 2002) means attending to the (invisible) work of infrastructures and to the ways in which infrastructures are turned around or destroyed—not through analytical acts but through their differential usages and meanings in everyday settings. Yet another strategy for making infrastructural work visible passes through design. Designing objects for interventionist purposes is a form of engagement that may invert existing, but as yet invisible, infrastructures (Winthereik submitted; see also Thorsen, 2016, this issue).

What this suggests, in more down-to-earth terms, is that studies of infrastructuring environments may benefit from sustained methodological reflection in the domains of STS, anthropology, and sociology, particularly as this pertains to the changing practices of ethnography (Star, 1999, 2002; Suchman, 2002; Lury and Wakeford, 2012). While infrastructures are potentially available for elucidation through a range of methodological approaches—including statistical surveys, document analysis, and virtual methods—conceptualizing them in terms of heterogeneous relations, as we do here, nevertheless privileges ethnographic methods, attuned to contextual dynamics of situated practices and agencies. Indeed, the contributions to this special issue all rely, one way or the other, on versions of ethnographic work. Beyond ethnographers learning to note some initially unnoticeable aspects of settings, attendant challenges extend to core questions of choosing and delimiting research sites where infrastructuring happens; positioning oneself in layered ecologies of knowledge; and handling issues of scalability, size, and extension. In turn, we will now take a brief look at each of these ethnographic challenges.

Taken as a collective corpus, STS may be credited with pioneering a novel ethnographic approach to science and technology. Through a focus on science and technology as entities in the making what had come to seem self-evident, universal, and true was denaturalized (see Law and Mol, 2001). As this special issue vividly illustrates, a similar approach to how environments are infrastructured proves a powerful tool of infrastructural inversion, serving to unfold some of the technical, ethical, and political choices that are, or have been, gradually embedded throughout their development (Bowker *et al.*, 2010, p. 99). In the vocabulary of sociologist Erwin Goffman, studying the work of infrastructuring will often mean going 'backstage', literally and figuratively.

Attending to the histories of infrastructures or to the present-day practices that make infrastructures function in a complex social and political reality is thus in part an attempt to search out the sites where consequential decisions on infrastructural design are made and implemented. One might do this by studying the social worlds of biological database builders, ecologists responsible for new nature

classifications, technical standard-setting bodies and NGO networks, engineers articulating sustainable technology protocols, amongst many other settings. This special issue highlights its own heterogeneous communities, as the authors gradually extend the infrastructural connections covered by applying methods of following people, data, and technical objects around, thus employing practical ethnographic means for exploring the sites and boundaries of the infrastructures under study (we return to issues of scalability below).

As already mentioned, infrastructures will often suggest themselves for further study in situations where they break down or otherwise malfunction (as with data-deficient species); or when they become the explicit object of social controversy (as with carbon inventories). One version of this is afforded by situations in which some aspect of the built environment—such as an eco-house or an urban planning project—is explicitly articulated as an experimental site of sustainable redesign. In such situations, mundane elements of infrastructures that would ordinarily remain invisible, like the electricity consumption of household appliances, undergo an identity switch and are redefined as notable moments of material public engagement in global environmental affairs (see Marres, 2008, 2012). In striking ways, voluntary attempts at sustainable design thus resemble a materialist version of the 'breaching experiments' made famous by sociologist Harold Garfinkel, in that they render visible aspects of the taken-for-granted urban infrastructure.[2] More generally, however, methods of studying socio-technical controversies serve as another hallmark of STS as a whole—and they can be usefully extended to questions of how environments are (or indeed are not) infrastructured in cases where breakdowns perform a kind of naturally occurring infrastructural inversion. Such methodological themes and considerations echo through several of the contributions to this special issues, not least those of Kimura, Morita, and Richardson.

Apart from such questions of which sites and situations to engage, ethnographies of how environments are infrastructured bring with them a heightened sense of 'reflexivity', in terms of positioning oneself within a layered ecology of environmental knowledges. Put simply, what (promise of) additional knowledge, exactly, does the ethnographer bring to the scene of infrastructuring work? Anthropologist Riles (2001) talks here of a 'collapse of epistemological distance' between analyst and object—an effect endemic to ethnographic work undertaken in modern knowledge cultures, including the cultures of ecological knowledge (see Blok, 2011). Within STS, such concerns have spurred a sizeable debate on the various terms of intervention, understood as possibilities for collaborative and transformative knowledge-making in various organizational contexts (Zuiderent and Jensen 2007; Jensen, 2008; Winthereik and Verran, 2012). Extending such debates, part of what they invite, arguably, is an attitude of experimenting with ways of infrastructuring environments. As Claire Waterton notes about archival work (2010, p. 666), STS researchers may conceive their role as one of turning infrastructure 'inside out', 'allowing it to be built from use, rather than from preconceived categories or even anticipation of use'.[3] Ethnographers of the work of

infrastructuring environments, we should acknowledge, are themselves part of the relational heterogeneity thereby emerging, themselves engaged in making or unmaking particular socio-ecological relations.

Finally, in this list of methodological challenges, researching the infrastructuring of environments entails difficult dilemmas of scalability, in that infrastructures extend across time and space, involving distributed ecologies typically linking thousands of people, computers, sites, and events (Star, 1999, p. 383). This challenge has generated novel debates and practices; for instance, the question of how to study computer infrastructures as they extend in time and space has been dealt with extensively within the field of Computer-Supported Cooperative Work (Monteiro *et al*., 2013). More generally, in temporal terms, scalar challenges arise in part from the fact that no infrastructure emerges from scratch and that changes take time; moreover, most infrastructures are built with a view to long-term future reliability, raising difficult questions about 'end points' (see Miyazaki and Riles, 2005). In spatial terms, recent enthusiasm for multi-sited ethnography suggests that the challenge of infrastructuring environments may in part be met by simply scaling up traditional fieldwork techniques (see Hine, 2007; Beaulieu, 2010). However, as Knoor Cetina (1999, p. 19) notes on her comparative studies into the epistemic cultures of molecular biology and high-energy physics: 'the great complexity of the fields investigated implies that the study could not possibly have been done by one person'. Research on the infrastructuring of environments, then, may well benefit from novel experiments in collaborative anthropology—a challenge which, admittedly, is only indirectly taken up by the contributions to this special issue (but see Choy *et al*., 2009).[4]

In sum, this section has attempted to give ethnographic flesh to established calls for methods of infrastructural inversion, exemplifying how such gestalt shifts may play themselves out in studies of the infrastructuring of environments. Such studies, we argue, raise a number of pertinent challenges to an ethnographically informed STS: which sites and situations to study; where to position oneself within existing ecologies of knowledge; and how to scale up in order to deal with the temporal and geographical extension of infrastructures? While in no way claiming to solve these issues, the contributions to this special issue all pick up the challenges, in specific and divergent ways, thereby exhibiting also a range of possible avenues for future work. Before we move on to sketch how each contribution allows us to ask novel questions, however, we want to briefly reflect on some of the ethical–political coordinates inevitably at stake in this shared research space—by way of taking certain novel attempts at the boundary of STS, anthropology, and sociology as metonymical figures for how to study infrastructuring practices.

The Ethical–Political Work of Infrastructuring

Our methodological approach to infrastructuring environments, as laid out so far, implies that the fraught intersections of specific (natural) environments and

(material) infrastructures can only be experienced and known from 'the middle out'. Any attempt at studying infrastructures in their 'full range', from some assumed privileged or global vantage point, will assume too much in advance and therefore risk losing out on the specificities and situated effects that infrastructure studies should hope to unearth. Such a methodological commitment, we now want to argue, also has important implications in terms of how we might, as analysts, seek to engage the ethical–political tensions and ambiguities at stake in any site and situation of infrastructuring environments.

Such tensions emerge, in part, on account of the ways in which contemporary sites and situations of infrastructuring environments bring us into contact with two essentially contested 'frontiers': those of the global (environment) and the future (of the collective) (see Law, 2004; Guyer, 2007). The notion of the anthropocene, for instance, clearly indexes these two frontiers, albeit in highly selective ways. Yet, they are also empirically present, in equally specific ways, on the ground and across numerous settings where the mundane work of establishing, using, or redesigning infrastructures is taking place. In present-day Peruvian frontier towns, for instance, road construction consortiums and the national government are under pressure from investors and NGOs to take environmental and health impacts into account (Harvey and Knox, 2008). Within the ensuing controversies, Peruvian and international NGOs, in particular, put into play a set of ethical standards thought to be internationally applicable—thereby exemplifying how the work of infrastructuring partakes to situated globe- and future-making projects. Here as elsewhere, however, such projects readily find themselves wound up in-between the constitutional moments of forging common standards, on the one hand, and the sometimes painful realization of deep ontological chasms, on the other (Choy, 2005; Jasanoff, 2003; Latour, 2004; Nielsen and Pedersen, 2015).

Rather than search for well-defined ethical–political criteria for how to evaluate such 'awkward encounters' (Tsing, 2005), let alone attempt to define their political ontology once and for all, we find it productive to present here a few conceptual figures, serving as metonyms for how one may approach the ethical–political work of infrastructuring environments. We take these figures from recent and influential contributions to STS, anthropological, and sociological discussions on infrastructures—and we select them, in part, for their shared empirical focus on roads and road-making. As such, roads stand in here, we might say, for the more general ambiguities of infrastructuring environments, in ways that make visible certain analytical cum ethical–political dilemmas.

To phenomenologist Ingold (2010), roads—and the transport across homogenous surfaces they allow—are part and parcel of the drama of modernity, by which the earth becomes a platform, or infrastructure, placed not *in* but *above* the ground. The opposite of the road, to Ingold, is the path, along which the wayfarer moves on a ground that is infinitely variegated and composite, feeling the light, moisture, and currents of the air. The wayfarer leaves behind footprints

and paths; transport leaves behind a hard-surfaced engineered environment. In this analytical set-up, infrastructures are always existential epiphenomena, but paths are nonetheless favored above roads as places to look for sociality: 'quotidian life proceeds for the most part along winding paths' (Ingold, 2010, p. S127). Moreover, given that the ground is where plant and animal life bursts forth organically, the very notion of infrastructuring environments, from this perspective, becomes oxymoronic. Such sensibilities, we believe, must be taken seriously, in part because they undoubtedly play important roles in environmentalist thinking, feeding various anti-infrastructural struggles. Analytically, however, Ingold's clear-cut distinction between the road and the path seems to us to lose too much productive ambivalence.[5]

To French neo-pragmatist sociologist Thévenot (2002), in turn, the road—in his case a particular highway running through the French Pyrénées—comes to signal all of the moral complexities that result from the furniture or 'equipment' of humanity. Like other technical interventions, contemporary roads trigger an intricate grammatical web of moral evaluations, according to which it may be qualified publicly in starkly differing terms. While the road qualified as an efficient industrial infrastructure for future markets dominate public debate, environmentalist or green critiques exert considerable pressure, given the natural qualities of the area. The end result is a compromised road: in response to critique, the design comes to include tunnels for frogs and bears, and bicycle paths are made to border it on each side (Thévenot, 2002, p. 67f). On this account, the work of infrastructuring environments signals the *inherent* moral ambiguities of how humans attach themselves to the non-human world, with resultant nature-cultures often arising from pressures of compromise (see Maguire and Winthereik, forthcoming).

Finally, in their ethnographic rendition of road-building efforts in Peru, Harvey and Knox (2008) depict the road as an object of divergent passions, as holding the promise of transformative potentials through modern networked connectivity. In the capitalist frontier zones of Peruvian gold mining and logging towns, roads trigger an array of unlikely and unpredictable convergences among actors 'otherwise engaged', from the World Bank to governments, international NGOs, informal public opinion, and unregulated economic activity. In stark contrast to shifting and critical attitudes in Euro-America, local communities use road blocks and hunger strikes to demonstrate the strength of their desire and political will to ensure that new roads pass through their backyards (Harvey and Knox, 2008, p. 81). While such boom and bust economies have had devastating consequences for the physical environment in many places, people respond to changes in land and new road connections by exercising creativity in the domains of hunting and trading. In such frontier zones, infrastructuring environments come to stand for *vital energies*, at once innovative and disruptive, by which people channel their shifting passions.

In short, analytically beginning in the middle rather than from some notion of epochal change implies attending to diverse forces of infrastructuring practices

and to the processes through which new *common* natures and cultures, or rather nature-cultures, are painstakingly being created from the ground up (Latour, 2004). In whichever specific and contingent ethical–political form, such a 'cosmo-political' perspective differs in important ways from the anthropocene movement's uniform call for urgently attending to the consequences of human activity on a global scale. As will be clear from the contributions that follows, unfurling tensions between the technical and the social; the natural and the cultural; the bureaucratic and the quotidian; the past and the future; the local and the global in specific cases of organizing and knowing environments is indeed far removed from diagnosing epochal changes to a singular global environment. As we demonstrate with this special issue, infrastructuring environments epitomizes attempts to construct nature-cultures that hold together, for some time and across space, in ways that remain accountable to those situated forms of life affected by their workings.

The Contributions: New Questions, New Interventions?

By highlighting some of the locally embedded and materially heterogeneous equipment making up the substratum of widespread ideas of the global environmental crisis, we have attempted here to locate the importance of attending to work of infrastructuring environments. In the various contributions making up this special issue, the authors in each their way relate notions of global crisis and alternative futures to ethnographic studies of the diverse ways in which infrastructures channel how specific environments are known and acted upon, often in conflict-ridden ways. In each case, infrastructures form complex ecologies of practice (Stengers, 2005), involving the relational heterogeneity and contested mediation of multiple protagonists, projects, and materialities.

What exactly comprises the infrastructure under scrutiny is different in each case, as is the analytical and methodological strategies adopted for their study. Some authors point to the importance of certain often-overlooked, yet influential material practices and political devices by way of which landscapes, culture, and sociality come to be organized within historically layered infrastructures, even as these prove vulnerable to the 'unruly' forces of nature (Kimura, 2016; Morita, 2016). Others highlight the work of articulating and contesting otherwise taken-for-granted material infrastructures as matters of (un)sustainability concern, and the various forms of obduracy and malleability exhibited in the process (Morita, 2016; Richardson, 2016). And yet others are concerned centrally with the consequences of infrastructuring environments for political action and with whether and how decision-makers in different contexts acknowledge such infrastructures as part natural, part technological, part cultural and social (Asdal and Hobæk, 2016; Schick and Winthereik, 2016). Individually and collectively, the contributions thus serve to open up novel questions and lines of inquiry, pointing towards a timely and renewed focus on infrastructures at the intersection of STS, anthropology, and environmental social research.

The contributions all in different ways focus on the *work* of infrastructuring environments. The work of infrastructuring environments can be both material, such as erecting seawalls for protecting against tsunamis in Japan in the case of Kimura (2016), and political, such as making laws about restricting whaling in Norway (Asdal and Hobæk, 2016). In presenting these studies, narrating from quite diverse practices, the special issue describes and conceptualizes the work of infrastructuring environments as happening in and through contested settings amenable to various kinds of intervention and change. Overall, even as asymmetries of power and knowledge clearly continue to matter centrally, the analytical impression, we hope, is far removed indeed from the time when infrastructures connoted the 'fixed facilities' holding society and nature in place.

Activating infrastructure by turning it into a verb, instead of keeping it as an noun, has certainly had the effect of alerting authors to the key question of who and what exactly is acting in and on specific environments, often in asymmetrical ways.[6] However, at the same time, the contributors all show how infrastructural agency is inherently hybrid, distributed, and mutually entangled. Sometimes, indeed, it is the infrastructure itself that begins to 'act' (Richardson, 2016); and in all the cases, questions of who produces what local–global environment tends to be blurred rather than clear-cut. This is the backdrop, indeed, against which questions of accountability and critical public engagement acquire their key significance, as highlighted in several of the contributions.

Insisting then on working from the middle and outwards—in both socio-material and ethical–political senses of this phrase—the contributors also share a certain willingness to *risk* their own position in the work of infrastructuring. As ethnographers, historians, and STS analysts, they take positions that guide them *into* the complexity and complicatedness of infrastructures and environments, while eschewing the fictitious places from where an infrastructure's relations to specific environments would be easily overlooked. The risk is a palpable one since, being situated in the middle, literally everything may be or become the 'infrastructure'—the taken-for-granted backdrop or substratum—for everything else (Carse, 2012). How, under such conditions, are we to make distinctions and settle the question of who is responsible for the effects of infrastructuring environments? From within their different settings, the contributors all respond to such questions of responsibility, thereby providing us with novel tools for scrutiny and experimentation on the vexed ethical–political ambiguities of infrastructural work.

Risks and ambiguities involved in infrastructuring environments are highlighted by post-3.11 reconstruction efforts in northeast Japan. In this conflictual context, Kimura (2016) argues, one way of staying accountable to the local communities most adversely affected by the triple disaster is to insist on the visibility, dynamism, and negotiability of all infrastructures. Attending to coastal Japanese infrastructures and their situated effects on specific human and non-human

environments, in this sense, also becomes a way of fighting the wider tendency to forget the specific hardships wrought in their wake, past, present, and future.

As readers of Kimura's contribution, moreover, we are reminded of the crucial sense in which the globalized spectacle of nuclear breakdown occurring in Japan in 2011 is embedded in a much wider meshwork of localized infrastructural histories and tensions, played out in specific nature–culture relations. Indeed, similar effects of a local–global reversal and reassessment—another infrastructural inversion, of sorts—may be detected in all of the contributions that follow. This, as we have argued, is exactly where the analytics of infrastructuring environments makes its most important difference to the increasingly urgent research agenda arising at the intersections of STS, anthropology, and environmental crisis. Rather than preempt questions of focus and accountability via established notions of a singular global environmental predicament (viz. the anthropocene), infrastructuring environments invites attention to those multiple settings of entangled encounters where more-than-human lives are lived, known, and organized—and where local and global, material and social, science and everyday life meet.

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Notes

[1]See the project's web-site: http://eiam.hus.osaka-u.ac.jp/

[2]We owe this observation to STS scholar and political theorist Noortje Marres (personal conversation).

[3]Waterton makes this argument in reference to studies undertaken in Australia by Helen Verran and Michael Christie, working together with Aboriginal indigenous groups in using digital technologies to record and store their knowledge of places. As this example shows, work of infrastructuring environments needs in no way to be confined to sites of ostensive bureaucratic or scientific power.

[4]Indeed, the *Matsutake Worlds* research project from which this reference stems, headed by anthropologist Anna Tsing, in many ways exemplifies the promise of infrastructuring environments research, for its ability to link issues of science studies, cultural anthropology, and global political ecology. One offspring of this collaborative work is taken up in the review essay by Nakazora in this special issue.

[5]In fact, we would rather prefer to blur the distinction altogether, for instance by positing the wayfaring practices of indigenous Amerindians along their mythical Milk River (in Amazonia) as one possible anthropological origin story for the concept of infrastructuring environments (see Hugh-Jones, 1979). We owe this observation to Amerindianist anthropologist Eduardo Viveiros de Castro (personal conversation).

[6]Taking the advice from the *Science as Culture* editor, this special issue underwent a slight change in title and thematic focus along its path of production, from *Environmental Infrastructures* (the name of the Japanese–Danish research network) to *Infrastructuring Environments*.

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