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Connecting the Empire: New Research Perspectives on Infrastructures and the Environment in the (Post)Colonial World

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Connecting the Empire: Neue Forschungsperspektiven auf das Verhältnis von (Post)Kolonialismus, Infrastrukturen und Umwelt

In der Debatte um Infrastrukturen im Globalen Süden besteht weitgehender Konsens darüber, dass das (post-)koloniale Erbe eines der zentralen Hindernisse für die Gestaltung umfassender, nachhaltiger und angepasster Versorgungssysteme darstellt. Über die Entstehung und Entwicklung von Infrastrukturen in den ehemaligen Kolonien ist bisher allerdings wenig bekannt. Bis vor einem Jahrzehnt folgten die meisten Arbeiten Daniel Headrick's „Tools of Empire"-These (1981), die mit eher groben Pinselstrichen ein Bild von Infrastrukturen als koloniale Instrumente zur Ausbeutung und Unterwerfung nichteuropäischer Menschen und Umwelt zeichnete. Neuere Studien gehen über diese „diffusionistische" Perspektive auf Technologietransfer deutlich hinaus. An der Schnittstelle von Imperial-, Umwelt- und Technikgeschichte diskutiert der Artikel den aktuellen Stand der Forschung zu Infrastrukturen im Globalen Süden im 19. und 20. Jahrhundert und lotet neue Forschungsperspektiven aus.

Angeregt durch David Arnolds Plädoyer für eine interaktive, kulturell differenzierte und räumlich breit aufgestellte Technikgeschichte der nichtwestlichen Welt (2005) konzentriert sich der Aufsatz auf fünf wesentliche Forschungsstränge und -debatten: erstens, die Akteure des Technologietransfers mit ihren Beweggründen und Handlungsweisen; zweitens, koloniale Infrastrukturen als Teil und Ergebnis vielschichtiger globaler Netzwerke, Wissens- und Stoffströme, von Konflikten, Aushandlungs- und Aneignungsprozessen; drittens, die Bedeutung technischer Infrastrukturen für koloniale Identitäts- und Raumbildungsprozesse; viertens, ein kritischer Blick auf zentrale (technik-)historische Ansätze wie Thomas P. Hughes Konzept großer soziotechnischer Systeme, speziell hinsichtlich ihrer Übertragbarkeit auf den Globalen Süden; und schließlich Chancen und Herausforderungen einer Verknüpfung umwelt-, technik- und imperialhistorischer Perspektiven für die Infrastrukturgeschichte – und darüber hinaus.

Schlüsselwörter: Infrastrukturen, Umwelt, (Post)Kolonialismus, Literaturbericht, Theorie, Netzwerke

In the academic debate on infrastructures in the Global South, there is a broad consensus that (post)colonial legacies present a major challenge for a transition towards more inclusive, sustainable and adapted modes of providing services. Yet, relatively little is known about the emergence and evolution of infrastructures in former colonies. Until a decade ago, most historical studies followed Daniel Headrick's (1981) "tools of empire" thesis, painting—with broad brush strokes—a picture of infrastructures as instruments for advancing the colonial project of exploitation and subordination of non-European peoples and environments. This paper explores new research perspectives beyond this straightforward, 'diffusionist' perspective on technology transfer. In order to do so, it presents and discusses more recent studies which focus on interactive transfer processes as well as mechanisms of appropriation, and which increasingly combine approaches from imperial history, environmental history, and history of technology.

There is much to gain from unpacking the changing motives and ideologies behind technology transfer; tracing the often contested and negotiated flows of ideas, technologies and knowledge within multilayered global networks; investigating the manifold ways in which infrastructures reflected and (re)produced colonial spaces and identities; critically reflecting on the utility of large (socio)technical systems (LTS) for the Global South; and approaching infrastructures in the (post)colonial world through entangled histories of technology and the environment. Following David Arnold's (2005) plea for a "more interactive, culturally-nuanced, multi-sited debate" on technology in the non-Western world, the paper offers fresh insights for a broader debate about how infrastructures work within specific parameters of time, place and culture.

Keywords: Infrastructures, Environment, (Post)colonialism, Literature review, Theory, Networks

Colonial Infrastructures Beyond "Tools of Empire"

Infrastructures are the backbone of society. Technical infrastructures allow us to communicate with each other, supply us with energy, light and water, dispose of our waste, provide us with the means to travel fast and comfortably, and monitor humans and the environment. Soft infrastructures systematically accommodate our social needs—health, education, culture, and leisure, to name but a few. We take these public services more or less for granted. With the exception of roads and canals, however, most 'hard infrastructures' have not been around for much longer than the eighteenth and nineteenth centuries. They were reactions to the changing needs of modern industrialized and urbanized societies. Their introduction was a bumpy process, and access to these new and often expensive amenities was highly contested and socially restricted (van Laak 2001; Schott 2014; Engels & Schenk 2014). Infrastructures were also part of global technological exchange processes, and their dissemination as well as appropriation were affected by asymmetrical power relations and global processes, such as capitalism, imperialism, and colonialism.

Colonialism was not only an outreach into new social environments, however, but also into new material environments. Therefore, an analysis of colonial infrastructures cannot be undertaken without a thorough investigation of their environmental prerequisites and ecological consequences. "Accessing and controlling environments", as James Beattie has put it, "underpinned British imperialism" (Beattie 2012: 129). European desire for (tropical) commodities largely drove the imperial project. Technological infrastructures aided in the exploitation of colonial resources by enabling large-scale access, harvesting, and transportation, resulting both in dramatic ecological changes and the genesis of "modern" environmental awareness. Colonial environments were no mere objects of human agency, however. Even though technical designs and environmental factors cannot directly explain political outcomes, they were—and remain—vital influ-

ences on historical processes, shaping both the design and feasibility of colonialism in general as well as the implementation and operation of technological infrastructures in particular.

At the intersection between imperial history, environmental history and history of technology, this special issue investigates the emergence and evolution of infrastructures in different colonial and (post)colonial settings. This endeavor, as we argue in this introductory essay, requires a critical reflection on both our ontological categories related to infrastructures and on those narratives of technology transfer that move "from the West to the rest" (Ferguson 2011), which have guided most historical studies until recently. Being caught in the notion that what was particular to Western technological culture was its "enormous capacity for expansion and dominance" (Friedel 2007: 4), they frame Western technologies as omnipotent "tools of empire" (Headrick 1981) for the subjugation and exploitation of non-Western people, environments and traditions. This perspective, as we argue, misses out on vital aspects of the transfer, (everyday) life and social and environmental preconditions and impacts of infrastructures in the Global South.

In this essay, we present and discuss recent studies from history and its neighboring disciplines, which tell more complex stories and even counter-narratives to the "tools of empire" approach and explore directions for further research. We argue that there is much to gain from unpacking the changing motives and ideologies behind technology transfer; tracing the often contested and negotiated flows of ideas, technologies and knowledge within multilayered global networks; investigating the manifold ways in which infrastructures reflected and (re)produced colonial spaces and identities; critically reflecting on the utility of large (socio)technical systems (LTS) for the Global South; and approaching infrastructures in the (post)colonial world through entangled histories of technology and the environment.

Within the broad variety of power relations and spaces covered by the term empire in its broadest definition (see next section), we limit our scope to the European overseas empires in Africa and Asia, in particular the British Empire, in this volume. The early-modern European expansion to America, Europe's "white" settlement colonies in the USA, Canada, New Zealand, and Australia, as well as contiguous empires that formed a single linked territorial agglomeration, such as the Ottoman, Austro-Hungarian, American, and Tsarist/Soviet empires, or the special case of colonialization within countries (for example the Saami by the Swedish) will not be discussed here. On the time scale, this special issue concentrates on the period between 1870 and 1970—from the "high imperialism" of the late nineteenth century to the end of the post-war decolonization

process. Despite this general focus on the colonial period itself, papers occasionally address continuities and discontinuities between colonial times and post-independence as well—for instance, David Nilsson on the colonial roots and legacies of African urban water infrastructures (Nilsson, this issue)—and also take vital inspiration from post-colonial theory.

Terms and Definitions

In tune with the academic project of "provincializing Europe" (Chakrabarty 2000) as well as Shmuel Eisenstadt's (2000) call for conceptualizing "multiple modernities" (instead of simply universalizing the Western model), histories of infrastructures and technologies need to reconsider central assumptions, concepts, and terms when dealing with (post)colonial societies, including, for example, the large (socio)technical systems approach that has heavily influenced research on infrastructures in Europe and North America (see section IV). In the West, technological infrastructures were formative for both the rise of the modern city and the nation state (e.g. van Laak 2006; Schott 2014). This historical experience has shaped our understanding of what infrastructures are, and what they are not. The term itself started its career at the highpoint of European industrialization in the 1870s, when it was first used in France in relation to railway construction (van Laak 2001: 370; Gandy 2014: 2). Today, political and scientific conceptions of the term usually include both the notion of a centralized topology of technical networks, and the assumption that infrastructure service provision happens within a set of formalized relationships—and is therefore closely attached to the municipalities or the state. This rigid idea of highly regulated, all-encompassing infrastructural systems comes to its limits when applied to the urban and rural realities of the Global South (Monstadt & Schramm 2013). Here, a variety of ways for providing basic services were created, including complex arrangements of supposedly "old" and "new" technologies (e.g. the bicycle rickshaw) that substantially differ from—and challenge—our understanding of infrastructures and modernity alike. For a better understanding of these "parallel universes" of sometimes differing, sometimes merging and coexisting technologies and (social) environments, as well as of the colonial legacies of present-day infrastructures, a history of "technology-in-use" rather than a history of invention and innovation is crucial, as British historian David Edgerton pointed out in his seminal work *The Shock of the Old* (Edgerton 2007).

"Modern" infrastructures emerged in the Global South during the imperial age of the nineteenth and twentieth centuries, their development shaped by colonialism (see also section I). The political historian Ronald G. Suny defines empires as an "unequitable and […] very hierarchical relationship between a metropole and a periphery" (Suny & Martin 2001:

29). This relationship may be called "colonial" insofar as the extraction of resources, the assignment of ethnic identity and cultural attributes, and the concentration of political power serve metropolitan interests above all. Consequently, the subordination of certain societies or groups to others, as well as cultural constructions of difference relating to ethnicity, gender, intellect, and organizational capacity, are not only central elements of imperialism, but also form the ideological foundations of colonial infrastructures (Thomas et al. 2015: 1).

There are several environmental dimensions at play here (see section V in particular). First of all, the physical environment, encompassing geography, geology, ecosystems, and climate, along with the availability of natural resources, constituted vital preconditions for a number of infrastructures, in particular irrigation, sanitation, or energy projects, which in turn directly influenced their feasibility and character. Not only did natural resources and geographical parameters have an impact on infrastructural developments, but biological factors such as diseases also did. Secondly, disease was both a possible obstacle (in particular in Africa where transport was virtually impossible before the availability of malaria prophylaxis) and an unintended consequence (e.g. from irrigation). Thirdly, infrastructures also had major repercussions for environments, including pollution (such as river pollution by urban sanitation or air pollution from energy consumption); the alteration of habitats and migration patterns (not to mention extinction) of species; and changes of landscapes and sceneries as well as first attempts at countering ecological devastations, for example by establishing nature reserves or through "sustainable" resource management.

State of Research

The number of publications explicitly tackling the relation between infrastructures, colonialism, and the environment is still surprisingly small, both within Imperial Studies and the history of technology itself (Arnold 2005; for an overview, see also the readers edited by Howe 2010 and Harding 2011; regarding German colonialism, see van Laak 2004). The "New Imperial History" is primarily concerned with discourses, cultures, and spaces; the relation of knowledge, identity, and power; with networks and connections; race and gender issues; and the ambivalences of colonialism.[1] These debates have inspired many studies of the history of science, and medical issues in particular, especially the history of tropical medicine (e.g. MacLeod 2000; Harding 2011; Peckham 2015b). Infrastructures, urban technologies, and environmental issues have attracted less attention from practitioners of New Imperial History. There is considerable literature on the development, establishment, perception, and societal and ecologi-

cal impact of technological infrastructures in Europe and North America (see, for an overview, Hård & Misa 2008; Engels & Schenk 2014). The (post)colonial world, however, hardly ever appears in these narratives. It has, as we will show in detail, much to offer to address the "need for new stories" that Mikael Hård and Andrew Jamison (2005: 1) have proclaimed for the history of technology (Heymann 2013), for example, the creative domestication of modern technologies in the Global South.

Another field of research that would profit from a grounded investigation of infrastructures and environment in the (post)colonial context is the growing field of global history. It is little surprising that in the recent monumental works on global transfer, transportation, and translation processes, infrastructures feature prominently (Bayly 2004; Osterhammel 2014). They do so, however, only as means of improving global connectivity and mobility. Jürgen Osterhammel, for example, compares the "globalization effects" (2014: 715) of different transportation technologies. The material cultures associated with infrastructures, their technical characteristics, and their environmental preconditions and impacts remain largely absent from this literature. A study of those aspects of infrastructures in the non-Western world would also challenge the conclusion of many global historians that globalization led to growing uniformity across the world (Bayly 2004: 2).

Most global histories are framed as stories of the "subjugation of the world" by Europeans, as the translated title of Wolfgang Reinhard's recent comprehensive work (2016) exemplifies. This is also the underlying metanarrative of postcolonial theory (Said 1993; Escobar 1995), which has inspired a growing number of studies in the history of technology (Moon 2010), especially on the Indian subcontinent (Sangwan 1991; Gupta 1998; Prakash 1999; Ramanna 2002; Rangarajan 2012). The vast majority of these studies discuss technology transfer to Asia, Africa and South America as an innately violent process: they provide accounts of how "new" superseded "old" and "Western" superseded "traditional" technologies. In contrast, scholars dedicated to postcolonial techno-science have recently called for a "recognition of hybridities, borderlands and in-between conditions" (Anderson 2002) and suggested looking at contact zones as sites of "multivocality; of negotiation, borrowing, and exchange; and of redeployment and reversal" (Arnold 2005: 651). Similarly, we suggest here that metaphors of subjugation and elimination are not adequate as guiding concepts for future research on infrastructures in the context of colonialism and development. The studies introduced in this overview and published in this special issue present a range of other promising terms and concepts such as appropriation, hybridity, or coexistence instead of invention, dissemination, and subjugation.

This also reverberates with fresh insights from anthropologists who are dedicated to urban infrastructures in the Global South and take inspiration from postcolonial theory. Scholars such as Antina von Schnitzler (2016), Rosalind Fredericks (Diouf & Fredericks 2014), Brian Larkin (2008; 2013), and Hannah Appel (2012) can be credited for bringing in local users and entrepreneurs as self-conscious actors into the analysis of infrastructures in the non-Western world—and not only as passive recipients of Western technology. This attempt has probably found its most vivid expression in AbdouMaliq Simone's notion of "people as infrastructure" (2004). Simone proposes to expand the common understanding of infrastructure in physical terms to people's activities in the city associated with the provision of infrastructural services. The "incessantly flexible, mobile, and provisional intersections of residents," so typical for African cities today, "become an infrastructure—a platform providing for and reproducing life in the city" (Simone 2004: 407). This perspective offers a promising point of departure for historical studies of infrastructures in the Global South, which—also for reasons of accessible sources—have been rather concerned with materialities and Western "system builders".

In these historical studies, not all infrastructures feature equally. While there is considerable scholarship on irrigation, transport and communication—those infrastructures most vital to colonial development (see for example Leonhard & Hirschhausen 2011; Beattie & Morgan 2016)—research on urban technologies and their supportive infrastructures is only recently gaining momentum. Testifying to the prevalence of colonial history of medicine and urban geography, most works in the last twenty years focused on sanitary and urban planning issues.[2] Yet, other urban pollution problems, as well as the history of energy and electrification in the Global South, can still be regarded as a research lacuna, albeit with a growing field of practitioners.[3] Differences also exist in regard to the scholarly attention that different world regions have received: The history of technology of India, for example, is much better researched than that of sub-Saharan Africa, except for South Africa.

Still, with a few exceptions, most scholarship on infrastructures in the Global South is undertaken by Western-born scholars, who often face a set of methodological challenges. Amongst the most fundamental are limited language skills and lack of written sources that give an account of the perspectives of colonial subjects regarding the impact of technological infrastructures on everyday life (Cooper 2007). Here, historical research might profit from a more comprehensive use of oral sources and impulses from neighboring disciplines, such as anthropology, ethnology, and area studies. Findings from studies on today's energy use in the Global South (Wilhite 2005; Winther 2011; Boyer 2015), for example, suggest that

colonial subjects too were by no means passive recipients and consumers of "Western" metropolitan technologies, challenging an understanding of technology transfer that was held dear among historians of technology for a long time.[4]

Classical Narratives

Almost thirty-five years have passed since Daniel Headrick published his groundbreaking book *The Tools of Empire* in 1981, and it is almost twenty-five years since his follow-up study, *The Tentacles of Progress* from 1988 (Headrick 1981, 1988). The importance of key technologies such as steam power, quinine, or the machine gun to colonial rule that Headrick emphasized prominently is today more or less a given in most historical explorations of imperialism. According to this master narrative, technologies made it possible to realize colonial motives, enabling the exercise of imperial rule and rendering it economically viable. Consequently, new technologies profoundly influenced the timing, location, and nature of imperialism. With regard to infrastructures, most authors within this narrative have concentrated on "heroic," large-scale transport, communications, and military infrastructures as part of an ensemble of modern technologies which served the quest of penetration, conquest, and consolidation of new territories. There is a fair amount of literature on steamships, railways, telegraphs, and irrigation, focusing on their invention, refinement and distribution, on administrative and financial issues and their societal—and sometimes environmental—impact (Arnold 2005). Most texts are written either from an "imperial" or "subaltern" point of view, discussing them as examples of technologies of power, for better or worse. The story of how everyday technologies influenced colonial life and rule, however, especially regarding the twentieth century, has only been explored very recently (e.g. Arnold & DeWald 2012; Arnold 2013).

Beyond their instrumental character for colonial ventures, technology and science have also been investigated as means of self-affirmation for colonial subjects (e.g. Sangwan 1991; MacLeod 2000; Harding 2011; Bennett & Hodge 2011). One of the central works on this theme is Michael Adas' *Machines as the Measure of Men* from 1989. His key argument is that those involved in the colonies came to view scientific thought and technological achievements not only as vital attributes of European—and hence their own—superiority, but also as the most meaningful measures by which non-Western societies might be evaluated, classified and ranked. The application of modern technologies, production and management processes would result in both economic development and the "moral advancement" of the colonial subjects. Infrastructures were, therefore, right at the heart of the imperial "civilizing mission" (Fischer-Tiné & Mann 2004) both ma-

terially and symbolically, as the rhetoric of modernity and civilization was also an essential element of the self-representation of the West (Gupta 1998; Marsden & Smith 2005). For example, the Indian railways (and especially the bridges that spanned the great rivers of India) were heralded and praised as torchbearers upon the path of progress, signifying the superiority of European civilization and bringing enlightenment to the native heathen population. In addition to its practical purpose for transporting goods, passengers, and military equipment, the massive railway infrastructure was also supposed to produce awe in the minds of Britain's colonial subjects and to contribute to its basic legitimacy (Aguiar 2011).

Similarly to the history of technology, environmental history has produced its own classic "master narratives" on the relation of colonialism and the environment. Following the general inclination of environmental history for narratives of deprivation and loss, research has particularly highlighted the devastating (albeit mostly unintentional) ecological effects that European hunger for foreign natural resources had on the environment of their colonies. In contrast, indigenous environmental practices were often depicted as being in harmony with nature, with the introduction of modern "Western" technologies as an eviction from paradise; a romantic narrative also found in subaltern studies (e.g. Shiva 1989; Gadgil & Guha 1992; Park 1995). Areas of research included forest management, nature conservation, and—following in the footsteps of Alfred Crosby's seminal work on the *Columbian Exchange*—the transfer of species.[5] In this context, technological infrastructures, and irrigation in particular, were often framed as instruments for the subordination and exploitation of both colonial people and colonial nature, thereby mirroring the "tools of empire" approach.[6]

Deconstructing the "Classic Narrative"

These classic narratives on the relation between colonialism, technology, and the environment have been vital for developing a critical view of Europe's imperial legacy. By highlighting the "dark side" of technological (and scientific) progress, these studies more or less dispensed with the idea of modernity as a ubiquitous and benevolent process. However, primarily focusing on technologies as imperial instruments of power and on colonialism as an environmentally as well as socially devastating phenomenon, the "tools of empire" school still essentially argues within a "Manichean world of high colonialism" (Byerley 2005: 25) that interprets colonialism as an all-encompassing force. That narrative is caught up in the classical occident-oriented, modernist view on technology, in which European and North American actors are the driving forces in the invention and spread of artifacts and systems. Consequently, it largely interprets global techno-

logical (ex)change as dissemination from the top, implicating linear power relations with the colonized as passive recipients.

Current historical studies, as we will see, tell more complex stories and even counter-narratives: they provide instances of infrastructures becoming places of resistance against colonial rule and of unintended social, political and environmental consequences of infrastructure transfers, limiting or undermining the colonizers original intentions. They reject simple diffusionist or instrumentalist approaches, instead highlighting tensions of and within empires, complex global connections and interactive transfer processes (such as information and commodity flows); mechanisms of appropriation and resistance connected to technological innovations; and ambivalences of human-environmental relations in colonial and postcolonial settings (with regards to early colonial nature protection efforts, for example).[7]

This five-section essay provides a comprehensive overview and discussion of this body of literature, connecting it to the contributions of the special issue and delineating future research perspectives. It first traces changing motives for the transfer of infrastructure technology throughout different periods of colonial rule, highlighting the growing importance of development as an "organizing concept underpinning the relationship between metropolitan Europe and [the] colonial [periphery]" (Hodge 2013: 2). In contrast to earlier diffusionist conceptions, it secondly argues that the transfer and exchange of infrastructures was a complex and negotiated process that can be best understood by following the multilayered global networks through which ideas, technologies and knowledge circulated in all directions. Thirdly, it depicts the manifold ways in which infrastructures reflected and (re)produced colonial spaces and identities, especially in urban environments. It then explores whether the notion of large (socio)technical systems may support a better understanding of infrastructural developments in the (post)colonial context. Lastly, it outlines perspectives for entangled histories of technology and the environment by investigating resources and environmental conditions necessary for the establishment of technical infrastructures in the colonies, their ecological impacts, and effects on the experience of nature. In the outlook, we will then delineate four directions of research that we regard as particularly promising for future studies of infrastructures, colonialism, and the environment.

I. From "Tools of Empire" to "Tools for Development": A Historical Overview of Colonial Infrastructure Development

Until the late 1990s, both imperial historians and historians of technology favored diffusionist narratives, depicting colonial rule and technological change as straightforward top-down processes, with either beneficial

or devastating consequences. As more recent scholarship shows, neither their portrayal as civilizing blessings for the advancement of "backward" societies nor as "tools of empire" captures the variety of functions infrastructures assumed within the colonial project. While some forms of infrastructure were at the heart of military conquest and control, economic exploitation and resource extraction, others served on a much more mundane level as amenities for colonial urban elites or even as basic services for a broader group of users. Some infrastructures were staged to showcase colonizers' technological superiority; others were operating largely unnoticed in the background. Moreover, the available resources for transferring infrastructures from the metropole to the periphery varied greatly among and within different empires and changed over time.

Most colonial powers, after an initial predatory phase of conquest and plunder, adopted more constructive ways of exploitation, so infrastructures became inextricably linked to their increasing interest in managing overseas resources. Whether framed as *mise en valeur* in France or as Chamberlain's doctrine of "constructive imperialism," new brands of development promoted since the 1890s envisioned, for example, the construction of railways, ports and other lines of communication to open up the interiors of colonial territories and tap into their largely unexplored wealth of natural resources. Although hardly any of these ideas materialized before World War I, they laid the groundwork for an enhanced role of government later on. "Old" and "new" colonial powers significantly differed in their approach. "Older" colonial powers, most notably Great Britain, would channel their limited metropolitan resources for infrastructure development to their most valuable overseas possessions only—India in particular. In contrast, as Agnes Kneitz suggests in her case study of water infrastructures in colonial Qingdao in this issue, latecomers such as Germany or the United States were more inclined to invest heavily into their colonial possessions, not least to showcase their technological potency.

In the 1920s, both French and British colonial authorities released new plans and programs with the goal of a more systematic economic exploitation of their dependencies, but also with the notion of taking "trusteeship" over their colonial subjects more seriously. Here, public works and communications—additional railways, ports, telegraph networks, roads—received considerably more attention than "soft" infrastructural services necessary to improve "native" education and health care (Cooper 2002). Among the largest infrastructure investments were railways, dams and irrigation channels, which, along with new agricultural research facilities, were built to boost cash-crop production for export and balance budgets of colonial states. These included the high-profile Office du Niger project in French Soudan and the Gezira Cotton Scheme in British Sudan. Many projects,

however, remained rhetorical, due to lack of financial resources and political will to invest metropolitan money in the colonies. Most historians therefore regard the 1920s as a transitional phase of colonial development policy (Hodge 2013), situating the origins of the "proactive or developmental state" in the early 1930s instead.

With world market prices falling in the wake of the world economic crisis, the focus on cash crop monoculture turned into an economic deadlock. The key nodal points of imperial transportation and communication networks, railways and ports now frequently became sites for strikes and demonstrations. In some regions of the world, the colonial self-image of racial superiority and the "white man's burden" showed its first cracks. In South and East Asia, for example, the rise of Japanese imperialism began to undermine the asserted Western technological and civilizational superiority (Bayly 2006). Western colonial powers responded to the growing pressure from both inside and outside their empires by altering their development policies.

In the Colonial Development and Welfare Act of 1940, for example, Great Britain committed to spending more metropolitan resources in the colonies, emphasizing the improvement of "native development" and "social welfare" as part of broader economic considerations. Arguably, this shift from the "preservationist colonialism" of the 1930s to the "developmentalist colonialism" of the 1940s and 1950s (Cooper 2002: 197) marked the most profound change of pace and scope within which infrastructures were built and expanded in the colonial world. Development funding was stepped up as private investors, who had previously directed a large proportion of their overseas spending into infrastructure projects, increasingly refrained from infrastructure investments abroad. With public funding came the demand for greater state control of utilities as well as an appetite for high prestige, capital intensive projects—not least as a means to (re)legitimize the colonial mission in the face of nationalist movements growing stronger in many colonial territories (see e. g. Hoag 2013).

Infrastructures became a core element of colonial states' ambitions to effect and to manage socio-economic transformations by means of state-planning and the application of scientific methods. In his widely acclaimed (and criticized) book *Seeing Like a State*, James Scott provides a useful set of concepts to capture these large-scale attempts by authoritarian governments to engineer their social and natural environments (Scott 1998). For Scott, many infrastructure projects in the colonies were materializations of a "high modernist" ideology, a "muscle-bound version of the self-confidence about technical progress [...] the mastery of nature (including human nature), and above all the rational design of social order commensurate with the scientific understanding of natural laws" (Scott 1998: 4). As

Nilsson shows in the example of Uganda in this issue, this ideology shaped planners' and policymakers' imaginations far beyond the colonial period of how "modern" water infrastructures should look and thus "closed" them for innovation and adaptation in order to better suit the local context.

A number of scholars have begun to trace continuities from colonial to post-colonial times. Following independence, colonial experts became "consultants" working for states, private companies, or newly created development agencies; colonial ministries, research institutions and think tanks were renamed and incorporated in the organizational structures of French, Dutch, or British development policies. In many cases, governments of the independent states readily took up blueprints for large-scale infrastructure projects from their former colonial rulers, implementing them with the help of international development finance and technical cooperation (Frey & Kunkel 2011: 223). They inherited a system of technical education, paradigms of infrastructure development and management, and theoretical models of broader economic planning. For many governments of young states, these abstract models attained the status of a "salvation promise" (Speich 2008). And mega-engineering projects not only form vital infrastructural legacies of many countries of the Global South today, they also embody the "high modernism" of earlier days, in material as well as in discursive terms (van der Straeten 2015).

II. Networked Conceptions of Empire and Contested Transfers of Infrastructures

The substantial differences between colonial territories' natural and human resources, the degree of infiltration by European settlement, the geographic and cultural proximity to the metropole, and thus the strategic importance attributed to them all profoundly influenced infrastructure development in those territories. India, for example, often served as a laboratory for the development of new "colonial" techniques from irrigation to railway building, later to be utilized both in Great Britain and in other Asian and African colonies. Recent works following the trajectories of commodities, techniques, resources, knowledge, and experts have revealed the importance of looking at cross-colonial linkages and inter-imperial exchanges within and across empires (for instance Ballantyne 2002; Beattie et al. 2015).

This set of connections does not fit in neatly with the classical "spokes in the wheel" model in which all connections are radial, linking colonial peripheries with its core, which has been critically discussed in the more recent historiography on the British Empire (Magee & Thompson 2010: 17–19; Andersen 2011: 163). Bennett and Hodge have argued that these connections should rather be understood through a "networked" conception of empire (Bennett & Hodge 2011). Papers of this special is-

sue thus follow the multilayered networks in which "multiple meanings, projects, material practices, performances and experience of colonial relations" (Lester 2006: 131) were shaped and circulated within and across various empires, highlighting the importance of (financial, material, social and intellectual) resources for the implementation of technologies and infrastructures. Ronen Shamir's contribution in this issue, for example, shows the decisive importance of specialist knowledge—in this case, the technical, topographical and hydrological knowledge associated with (hydro)power generation—in these processes and therefore directs attention to the agency of actor groups, which have only recently received more attention in the scholarship on the British Empire: the specialist advisors, experts, business leaders, and financiers of imperial project (Hodge 2007; Andersen 2011). An analysis of these actors as well as their agenda, strategies, resources, and social connections is instrumental for understanding how colonial technological infrastructures were shaped and transformed.

Relatedly, the networks themselves deserve particular attention in regard to their social formation and structure. Gary Magee and Andrew Thompson (2010) emphasized that access to networks was exclusive, for example tied to collective identities, such as Britishness. Their work suggests that Great Britain's lack of competitiveness in some sectors, for example in the field of electrical engineering (Shamir, this issue), could be compensated by its "non-market advantages" (Magee & Thompson 2010: 133) in the settler colonies, including professional diasporas, patent systems, business associations, and established lending practices and networks. To understand the infrastructural legacies of countries in the Global South today, there is much to gain from looking at continuities and discontinuities of these personal and organizational networks and the role of collective identities, especially in the transition from bilateral colonial development policy to the multilateral relationships of development aid (Öhman 2007; Hoag & Öhman 2008).

Casper Andersen's study (2011) of how imperialism and engineering became intertwined in Great Britain adds another important aspect to this debate on the transfer, or rather circulation, of technologies in colonial empires. He illustrates how a multitude of "imperial factors" shaped the engineering profession in the British metropolis itself: within its central institutions, its business platforms, the public perception of engineers, its ideological professional outlook, or in the form of assignments and revenues that were increasingly generated from imperial and colonial projects. These factors together resulted in an increasing internationalization of the engineering profession in Britain, signified, for example by the number of overseas members in engineer's councils, and also by the fact that despite the increasing professionalization of the field, a group of engineers with

privileged access to Westminster institutions tried to secure its exclusive, monopolistic position and remained critical to advancement (Andersen 2011: 2 f., 161).

This issue presents another example of how the Empire "struck back": The infrastructural preconditions for the "disposal" of human bodies have not received much scholarly attention until now. David Arnold describes in this issue how cremation technology, in practice in India due to ritual traditions, initially moved from India to the West and was appropriated there just to return to India in the form of "scientific" cremation, in turn devaluing traditional Indian burial practices as unhygienic. Arnold's rejection of the idea of technologies travelling one-way from center to periphery is not the only recent critique of the "diffusionist" conception of infrastructure transfer in the colonial world. Another one is the assumption of largely undisturbed and uncontested flows of technology and related ideas, practices, capital, and knowledge (or sometimes the lack thereof). This notion becomes increasingly questionable, as recent scholarship has provided fresh insights into the complex organizational process of constructing and managing technological infrastructures spanning great geographical distances, multiple institutional levels and cultural borders within the colonial world.

Infrastructures, as Maurits Ertsen has commented, cannot be understood as entities that were rolled out easily and evenly over colonized landscapes and societies. In his recent study of the Gezira scheme in the British Sudan, he argues that its classical portrayal as "a centrally planned, British colonial effort [...] continuously based on strong control over tenants and production" (Ertsen 2015: 7) tells only part of the story. He rather regards the project as a prime example of "contested development." He shows how realities on the ground were constantly being negotiated on all levels: between different governmental agencies and the private company managing the scheme, between management and inspectors within the company as well as between tenants and field staff. Another example can be found in David Sunderland's study of the Crown Agents who oversaw infrastructure projects on behalf of the British Colonial Office in the developed colonies (Sunderland 2007). Sunderland identified a multitude of problems along the chain of actors involved in planning and construction processes, spanning from the Colonial Office to the Crown Agents, and from consulting engineers to resident engineers, which frequently resulted in expensive, often uneconomic and at times poor-quality infrastructures.

With an increasingly globalizing market for infrastructure technology and enhanced technological and entrepreneurial capacities of colonial subjects, it was not even a given that metropolitan powers would reap the benefits from building and expanding infrastructures in the colonies, or

that they would even manage the construction process itself. In his contribution on the electrification of British-ruled Palestine in the 1920s in this issue, Shamir points out that control over political and legal means for the transfer of infrastructures did not necessarily translate into control over the actual technological, industrial, and ecological aspects of the process. Through their exclusive knowledge of local topographical, hydrological and economic conditions, the Electric Company in Palestine shaped the electrification process in a way that contradicted the initial intentions of the British Government of Palestine and the Colonial Office in London—resulting in the project being planned, supervised, and executed by a German company.

III. Infrastructures and the Production of Colonial Spaces and Identities

Following the spatial turn of the late 1980s, imperial historians have set out to understand the historical processes associated with the production of colonies as distinct, bounded spaces. In her study on the historical "production" of India as a nation-state, Manu Goswami proposes to understand the British Empire as a "scale-making project," in which the colonial state functioned as an "institutional mediation" between the global and the local in a political and economic sense. In her account, the introduction of new infrastructure technologies transformed the "geographical space of colonial India into an internal component of the imperial economy" (Goswami 2004: 49). A recent study by Fredrik Meiton on the early electrification of British colonial Palestine presents another approach on how to link the political history of the Empire with the transfer of infrastructures. Meiton looks at infrastructures as a material and discursive vehicle, translating and transforming political ideas, in this case the Balfour Declaration, into reality. Through its technical characteristics and the imagination of its creators, the colony's first large electric system "was central to the making of modern Palestine as a precisely defined geographical-political entity" (Meiton 2015: 978).

As much as infrastructures served as a force of economic integration of colonial spaces, they were also instrumental in their sociocultural division. In his comparative study of German colonial policies in Southwest Africa, China and Samoa, George Steinmetz concludes that modern colonial states "were permeated by the assumption of an unbridgeable difference between themselves and their subjects and of the ineradicable inferiority of the colonized" (Steinmetz 2007: 36). This "rule of difference" resulted in a "dual structure" of European colonialism (discussion in Hege 2015) signified by the binary couplets of primitive/civilized, tribal/Western, traditional/modern, or pre-capitalist/capitalist. Not surprisingly, identity politics has

become the lens through which most of the (few) existing studies look at infrastructures in the former colonies.

Most of these works focus on urban areas as the most important sites of colonial cohabitation. Significantly, the term "segregation" (in the context of at least some formal residential separation) arose about the same time as the discipline of town planning (Home 2013: 125). In the co-evolution of colonial cities and technical infrastructures, the latter often did not only reflect urban spatiality (Gupta & Ferguson 1997) or institutional segregation (Mamdani 1996), but were deliberately and in different ways used to (re)produce it: by delineating zones with different building regulations, colonial administrators not only created a factual racial division but also predetermined connectivity to infrastructures, which in turn was tied to property rights, stable tenure conditions and building standards. As Moses Chikowero has shown in his study of Bulawayo in colonial Rhodesia, the municipality devised specific programs to promote the electrification of European households while at the same time discouraging the African population from using it. In a very direct way, electricity was also used to police and discipline colonial subjects, for example by installing electric lighting in order to control unsanctioned movements under the cover of darkness (Chikowero 2007).

There is also a significant body of literature produced by urban geographers on "political infrastructures." Most of these works focus on water and sanitary infrastructures, arguably the most vital and contested urban services. In the planning and development of these infrastructures, the discourses of cultural and racial difference blended with ideas associated with sanitary reform in European cities in the late nineteenth and early twentieth centuries (Gandy 2008: 122). Following Warwick Anderson's (e.g. 2006) works on American public health in the Philippines, a number of scholars have shown how "imaginative geographies of contamination" and preconceptions of the colonial Other as uncivilized, polluting bodies informed the creation of urban secessionist networks and enclaved spaces in colonial cities like Lagos (Gandy 2006), Batavia (Kooy & Bakker 2008), Delhi (Mann 2007), and Bombay (McFarlane 2008). As Kneitz shows in her paper on colonial Qingdao's sanitary and fresh water infrastructures, colonial urban planning was thoroughly racialized, not only providing superior infrastructures to Europeans, but also creating separate sanitary and water supply systems for Europeans and native Chinese to guarantee maximum public health. Even after independence, such infrastructures of inequality were often carried forward, albeit on class instead of racial grounds, as Nilsson elucidates (also in this volume).

Reducing the collective identities that played a role in shaping colonial infrastructures to ethnicity, however, runs the danger of obscuring a mul-

titude of other factors, such as class, caste, or nationality. In the case of colonial Qingdao, for example, not only the German colonial administration, but also Chinese urban dwellers considered Chinese migrant workers from outside the city as a potential health problem. In addition, not all urban infrastructures were as socially exclusive as electricity or modern water and sanitation networks. In his article on the street life of modernity in late-colonial India, Arnold gives an account of how the street became a site of encounter between "modern" motorized transportation and earlier, seemingly "pre-modern" modes of traffic. His study provides an example of colonial urban infrastructures that might rather be regarded "as a vital public arena for the physical display, social utilization, and cultural assimilation of new technologies and hence the potentiality for ownership, control, and contestation over their daily use" (Arnold 2012: 141).

In light of this multitude of specialized, ethnically or socially exclusive and customized infrastructure networks and urban spaces, the modernist "ideal of integrated, singular infrastructures […] so recently central to policy thinking and ideology" (Graham & Marvin 2001: 9) in the Western world becomes questionable. What can one make of these examples that seem to contradict the taken-for-granted world of networked urban infrastructure as many of us know it today? Simon Marvin and Stephen Graham regard the increasing fragmentation of urban infrastructures and experiences of the city, caused by contemporary processes of deindustrialization, privatization and the reallocation of state resources, as manifestations of "splintering urbanism" (see also Graham 2009). While this narrative applies to a number of (especially Western) urban contexts, most cities in the former colonies reveal an urban fabric that has always been splintered, unequal, and contested (McFarlane 2008). Connecting urban historical geography with theories of how large technical systems emerge and transform over time can help to shed light on the historical roots of splintered urban networks and spaces in the Global South, as well as provide new insights into current processes of Western urbanization.

IV. "(Post)colonial" Large (Socio)technical Systems

Research on infrastructures often draws on Thomas P. Hughes' 1983 concept of large (socio)technical systems (aka LTS—Hughes originally used the term "technological" systems) (Hughes 1983), one of the most influential theories in science and technology studies of the last few decades (e.g. van der Vleuten 2006). Scholars often regard it as universally applicable, but it is typically applied to the "Western" world (Moss 2014: 1435). This special issue explores whether the LTS approach may support a better understanding of infrastructural developments in colonial contexts, but also

challenges this established narrative with regards to non-Western regions of the globe.

The LTS approach emphasizes the juxtaposition of technologies and society, regarding technological systems as both socially constructed and society shaping. Highlighting connections among human beings, material objects, organizations, institutions, and the environment, Hughes perceived infrastructures and technologies as part of a complex web of interactions, with a couple of decisive "system builders" (such as inventors, financiers, and managers) at its very heart (Hughes 1989). Hughes identified four typical phases of system evolution: invention and development, technology transfer, growth, and consolidation. Patterns might vary, however, depending not only on national styles, but also the dynamics of the system in question. As systems evolve, they acquire "momentum" and become prone to "reverse salients", inhibiting adjustment to topical challenges as they increasingly follow established trajectories. These processes might not only cause path dependencies, but even result in "technological closure," rejecting (outside) influences and innovations to the system. The perseverance and obduracy of technologies and infrastructures has been widely discussed, especially regarding historical turning points and possible solutions to "lock-in" phenomena (on path dependencies, see David 1985; North 1991; Ambrosius & Franke 2015).

Despite its analytical appeal, the LTS approach has been subject to multiple criticisms over time (e.g. König 2009: 90–93; Moss 2014: 1434–1436). These include methodological problems (as it proved quite difficult to operationalize because of the many system components involved); general reservations, for example regarding its teleological tendencies or the (little conceptualized) juxtaposition of LTS and society; and specific objections, in particular the overemphasized importance of system builders as the major agents of change. LTS has also been accused of being overtly "Western-centric," with its relevance to other regions of the world still up for debate. Such debates open up fruitful areas of discussion not only on possible similarities and differences among world regions, but also on processes and agents of transnational technological transfer and change.

Are there features particular to the evolution of infrastructures in the Global South during colonialism as well as after independence? Who were the decisive colonial "system builders?" Did colonial paradigms result in infrastructural continuities or discontinuities from colonial to post-colonial states and societies (e.g. McFarlane 2008; Huillery 2009; Gandy 2006, 2014), and did infrastructures "store and execute" power despite political change (Engels 2010: 64–67; see also Kneitz and Nilsson in this volume)? Recent studies indicate that patterns of system development might vary considerably. Electrification in countries outside the industrial core of-

ten began with later developmental phases, omitting, for example, the early stages of invention and development (Showers 2011), or needing to find alternative directions of growth, as load factors did not encourage an economies of scale approach (Shamir 2013: 4). Sometimes service providers deliberately disregarded potential customers on racial grounds (Chikowero 2007). Empirical studies on the emergence and development of (post)colonial infrastructures therefore not only promise fresh insights into the evolution of large technical systems in different socio-cultural, political and environmental contexts, but also into possible conceptual blind spots of the LTS approach itself.

As Nilsson points out in his paper on Africa's urban water systems, technologies frequently reached (ex)colonies at a time of supposed technological "closure," with state actors and international developmental organizations either unwilling or unable to adapt Western models to local needs and restrictions. He questions the assumption that large technical infrastructures are the most effective means of providing "modern" infrastructural services, which, for example, neglect the importance of informal arrangements and small-scale "appropriate technologies" (De Laet & Mol 2000; Radkau 2008). In doing so, Nilsson inquires how large technical systems might be adjusted to fit the informal economies of the Global South with their different, and additional, sets of institutions and governance structures. He also articulates the possibility that countries of the Global South might have adopted their own technology paths in providing infrastructure services, possibly differing substantially from those in the West, and consisting of individual mixtures of "old" and "new" technologies. This is another history of technology approach of great promise that has not been explored to its full extent in colonial contexts yet (Edgerton 2007).

If we wish to avoid straightforward "tools of empire" stories, we moreover need to analyze the fullness of system interactions and actors, not just the (colonial) "system builder" at the top. Drawing on Latour's actor-network-theory, Shamir (2013) suggests looking at the "unflattened" landscape of infrastructural development, giving equal attention to the activities of governments and electricity meters, private companies and consumers, legal arrangements and natural resources. Looking at technical infrastructures as both actors and actor networks, the dual character of infrastructures as mediators and intermediaries becomes visible. Technologies and infrastructures are not just "tools of empire," transferring and implementing the political agency of their creators as pure mediators would. As intermediaries, they also actively—and unpredictably—shape history, sometimes even following their own "intrinsic logic" (Berking & Löw 2008; Monstadt & Schramm 2013).

To unravel the dynamics of infrastructural development and change, a closer look at the material and immaterial components of large technical systems and actor-networks might also be fruitful. As findings from the new institutional economics and social sciences show, formal and informal institutions such as rules and regulations, but also values, preferences, and beliefs are vital prerequisites and instruments of both governmental policies and governance processes (e.g. North 1991; Bromley 1991; Mayntz & Scharpf 1995). They are also essential tools for the transmission of technologies and implementation of colonial rule into daily life practices. Despite Hughes highlighting the significance of institutional arrangements for technological change and the development of large (socio)technical systems, formal and informal institutions have hitherto received little attention in both history of technology and imperial history (see also Bernhardt et al. 2009). Such an "enriched" large (socio)technical systems approach, focusing on actor-networks, institutions and the material components of technologies might be a useful instrument for both long-term historical studies of (post)colonial infrastructures and for developing possible solutions to current infrastructural problems in the Global South (see also Nilsson, this issue).

V. Entangled Histories of Technology and the Environment

In European and (to a lesser degree) North American academic discourses, environmental history and history of technology have long been entangled (see Reuss & Cutcliffe 2010; Russell et al. 2011; Pritchard 2014 for instance). In both disciplines, urban or rural technical infrastructures were major areas of research from early on (e.g. McNeill 2000; Radkau 2000). In research tackling the relation between colonialism and the environment, however, technical infrastructures have received considerably less attention (on recent trends in environmental history, see Sörlin and Warde 2007;[8] Beattie 2012; Isenberg 2014), as most studies so far have concentrated on the ecological preconditions and environmental impacts of colonialism in general, particularly with regard to forest management and agriculture, for example deforestation, erosion, or the extinction of species (e.g. Radkau 2000; Burke & Pomeranz 2009; Rangarajan 2012). Another focus was (and is) on the emergence and specific quality of colonial nature conservation (Grove 1997; Kirchberger 2010; Ross 2015; Gissibl 2016). While technical infrastructures often feature in these stories, they were rarely at the center of analysis.

In accordance with their importance for the colonial project, irrigation and transport as well as sanitary issues attracted the most attention so far (e.g. Beinart & Hughes 2007; Beattie 2012). As to irrigation,[9] the British in particular implemented a great number of schemes over time to further the

cultivation of "cash crops" (chiefly cotton), especially in India and Egypt with their long tradition of hydraulic engineering that the British both aimed to study, emulate and advance (Beinart & Hughes 2007: 130–147). Agriculture via irrigation canals not only embodied both Western technological superiority and its benevolent "civilizing mission," they were also a means to extend control over the environment in a centralized and integrated way. The prospect of "finally" harnessing natural resources for their own benefit tempted the newly independent states to continue on this path and to see large infrastructural projects as the most promising way towards progress, modernity, and prosperity (see Hoag 2006 or Showers 2011 on the history of giant multipurpose dams).

Technological infrastructures as instruments for the subordination and exploitation of both colonial people and nature feature strongly in Headrick's "tools of empire" approach—both in the original 1981 book and its 2010 "environmental update," *Power over People* (Headrick 1981, 2010). Headrick not only highlights how environmental factors benefited and advanced colonialism, but also how they worked as natural barriers and obstacles to be overcome, determining the nature and pace of colonial enterprises. In stark contrast to the New World, whose environment largely favored European conquest (often temperate climate and little health risks with Old World diseases decimating the indigenous population, see Crosby 1972; Diamond 1997; Nunn & Qian 2010), environmental factors in Africa for a long time marked the limits of European imperialism. Great distances, difficult terrain such as mountains, deserts or jungles, unpleasant climatic conditions, and especially diseases held potential conquerors at bay (Beinart & Hughes 2007). How medical and technological advances, such as quinine prophylaxis or iron-hulled steamers, over time aided in overcoming these (or similar) natural obstacles has been a major topic of research. Such research emphasizes not only the "ingenuity" of European engineers, but also the importance of indigenous environmental knowledge for these endeavors, including mechanisms and networks of knowledge transfer such as botanical gardens and societies (see Brockway 1979; Drayton 2000; Beinart & McGregor 2003; Schiebinger 2005; Axelby & Nair 2010; Beattie et al. 2015 for instance).

In turn, the limits and limitations of colonial environmental knowledge have also come to the fore. Regarding dam construction, for example, the highly seasonal nature of most African rivers presented a serious challenge to European engineers. As a matter of fact, it took several decades of experience for colonial officials and businessmen to even fully appreciate the problem (Showers 2011: 197; Hoag 2013; see Weil 2006 on India). As many European colonists discovered, what might seem appropriate in Great Britain or continental Europe could be disastrous on the other side

of the world, as the transfer of Western infrastructures and technologies resulted in unforeseen consequences. Irrigation and canal building, for example, often resulted in waterlogging, flooding, and salinization, undermining the "hydro-resilience" of colonial landscapes and people (Beattie & Morgan 2016: 2) and requiring extensive (as well as expensive) follow-up engineering works (e.g. D'Souza 2006). Irrigation also promoted waterborne diseases, such as malaria, hookworm, or bilharzias. Steam navigation and railways helped spread these diseases to formerly unaffected areas, culminating in the global typhoid, cholera, and plague pandemics of the nineteenth century (Beinart & Hughes 2007). Comprehensive transport infrastructures also accelerated the "biological invasion" of foreign species, significantly altering ecosystems around the globe, as Alfred Crosby elucidated in his influential 1972 analysis of the *Columbian Exchange*. Sometimes, such environmental-technical feedback loops inadvertently hampered other infrastructural schemes and gave rise to conflicting interests, such as rural irrigation, urban water supply, and hydro-electric works competing over scarce (water) resources and undermining each other in the process.

Research has also highlighted the importance of natural resources as a motivating force for colonial endeavors. Colonialism was to a significant extent fueled by the desire for raw materials and goods from Africa, Asia, and the New World, from sugar and cotton to precious minerals and crude oil and—most infamously—human beings (e.g. Mintz 1985; Beckert 2014; Uekötter 2014). As William Beinart and Lotte Hughes have pointed out, such commodity chains and resource frontiers gave the British Empire both its character and unity (2007: 2). Many important colonial cities, for example, were ports or inland nodes of traffic, sucking in natural resources and raw materials from their hinterlands and bundling them off toward the metropole or white settler communities (Beinart & Hughes 2007: 152–158; Botha 2005; Showers 2011). Exploring what might be called the "colonial metabolism" (see Cronon 1991 on urban metabolism, as well as Kneitz in this issue on the complex environmental relations between colonial Qingdao and its hinterland) and exposing the devastating ecological effects of Europe's hunger for foreign natural resources have been major impulses in colonial environmental history so far, spawning a number of resource histories on colonial commodities in the process (e.g. Kreike 2013; Beattie et al. 2015).

Resource and commodity flows also formed the material basis of technological infrastructures (see Hollstein & Straus 2006; Bair 2009; Evenden 2011; Topik & Wells 2012). In line with current trends of global and imperial history emphasizing transnational transfer processes and entanglements, tracing colonial "eco-cultural networks" between and within empires is

one of the most topical and promising research approaches in colonial environmental history today (e.g. Beattie et al. 2015a). Targeting eco-cultural commodity frontiers to explore human-environmental interactions, exchanges and relationships, from colonial rice and tea plantations to hunting practices, animal husbandry, or production of climate knowledge, the authors in this book specifically focus on connections beyond the political-administrative borders of nation-states and territories, in particular informal actor networks and knowledge transfer. While breaking new ground with regard to eco-cultural entanglements of and within empires, the volume primarily focusses on rural areas and does not discuss urban issues in detail (with the exception of Kheraj 2015).

With the exception of sanitation (see endnotes 2, 9), urban environmental problems constitute one of the most fundamental lacunas of colonial (environmental) history (Mann 2007: 3). In this issue, a broad range of city-environment relations will be discussed, from water supply of colonial Qingdao (Kneitz) to colonial legacies of Nairobi's water infrastructures (Nilsson), from electrification of Palestine (Shamir) to cremation and incineration in India (Arnold). Contrasting the burning of human bodies and the destruction of urban waste, Arnold's paper in particular tackles issues rarely discussed in colonial environmental research, emphasizing both specific local obstacles to the introduction of Western waste disposal technologies and the complex cultural connotations attached to environmental technologies and infrastructures. Research has repeatedly highlighted the ambivalences of urban infrastructures, their benefits, drawbacks and limits. Providing fresh water and sewerage systems had on the one hand improved public health, at least in the more affluent quarters, by reducing the impact of water-borne diseases (Beattie & Morgan 2016: 14). Drawing on broader discussions about the "rule of difference," research has also shown, however, how sanitary infrastructures (and, to a lesser degree, other urban infrastructures such as electricity or public lighting) created new spaces of inequality, specifically utilizing concepts of "nature" for this purpose (both in the sense of environmental conditions and human nature) (Gandy 2006; Mann 2007; McFarlane 2008; Kooy & Bakker 2008)—and carving out enclaves of European urban spaces in foreign "hostile" environments in the process (e.g. Chang & King 2011).

Scrutinizing the urban metabolism of Tsingtao, Kneitz depicts the complexities and difficulties involved in engineering colonial environments while utilizing technologies and concepts of nature originally developed for European climates, terrains, and social conditions, in this case, German-style scientific forestry and water management practices. All papers also demonstrate the limits of colonial infrastructures—whether urban or rural. Facing insufficient resources (such as financial restrictions or lacking

materials), local opposition, contradictory expert opinions, administrative delays, problems of upkeep, maintenance, and scale (such as population growth), as well as unexpected realities on site or unintended environmental consequences, even the most well-meant projects often failed to reach their goals, were reduced in size and scope, or sometimes failed to materialize at all (see Harrison 1994; Sivaramakrishnan 1997; Ramanna 2002; Beattie 2011 for example).

Outlook: Future Research Perspectives and Challenges

As this introductory essay has shown, the transfer of infrastructures has shaped the relationship between the Western and the non-Western world in a much more complex way than suggested by the original "tools of empire" approach. Research in the last few years has made significant progress in offering more nuanced accounts of (post)colonial infrastructures and in opening up new perspectives for an entangled history of technology, colonialism, and the environment. This includes a profound analysis of the motives, ideologies and technological paradigms behind the transfer of infrastructures to the colonies and ex-colonies. The review of recent literature furthermore shows that straightforward "diffusionist" approaches were complemented and superseded by "networked" concepts of empire, tracing complex webs of ideas, practices, resources, and stakeholders within and across empires that exceeded and subverted "official" center-periphery relations. In the process, formerly neglected agents of transnational technological transfer and change, for example business owners or engineering consultants, but also formal and informal institutions have received more attention—even though most studies still focus on Western actors within these networks. Finally, research generally has become more aware of the importance of the material dimension of colonial rule: not only the artifacts, resources, technologies and infrastructures involved, but also the environmental prerequisites, challenges, and effects of colonialism.

As the papers of this volume show, pursuing such an entangled history of technological infrastructures, colonialism, and the environment has immense potentials to overcome current biases and limitations, widening the scope of investigation to formerly neglected areas, topics, and actors, putting "classic" theories and assumptions to the test, and retelling familiar stories with new twists to the tale. The articles trace the complex itineraries of cremation and incineration technologies between Great Britain and India; delineate the multiple layers of practices and meanings as well as urban-rural connections in Qingdao's water infrastructures; deconstruct

Britain's imperial ambitions in "electrifying the empire," and critically assess the colonial legacies of African water infrastructures that have proven unsuitable for the conditions on site. The papers also put the "classic" history of technologies theories and assumptions to the test, particularly the LTS approach. Not least because they investigate the manifold ways in which infrastructures reflected and (re)produced colonial spaces and identities, often resulting in the exclusion of local actors in design and use of infrastructure technologies, but also because they highlight divergent dynamics of technological change and appropriation processes quite different from Western experiences.

Of course, much work remains to be done as many technologies, periods and regions have either not been touched upon yet in historical investigation or discussed separately without drawing out possible connections and shared characteristics. Even highly visible and prestigious technological infrastructures such as irrigation, railways, or electricity need to be further unpacked in order to reach an analytical depth matching the study of infrastructures in the industrialized world. While the studies discussed in this essay provide fresh insights on the question of how Western technology impacted (and partially also, how they were influenced by) non-Western societies and environments, they might foreshadow an even broader debate in the history of technology, a discipline especially dominated by scholars from Europe and North America (this volume being no exception) and rooted in Western experiences of technical modernity. In the next paragraphs, we will outline four avenues of research that we deem particularly promising for future entangled histories of infrastructures, colonialism, and the environment. While some of these aspects have already been touched upon, either in our introductory essay or in the papers of this volume, others might offer impulses to move the boundary even further. For this purpose, we first argue that beyond expanding the focus of the history of technology to the Global South, we need to challenge some of the fundamental notions and concepts held dear to historians of technology for a long time; second, that a critical evaluation of the LTS approach for explaining infrastructural change is necessary; and third that historians need to shift perspectives toward the everyday life and appropriation of infrastructures. Finally, we suggest that this endeavor will also help to gain a better understanding of the current processes of global infrastructure transition.

First, it is not enough to (finally) expand our areas of reference to include the countries of the Global South—whether during colonialism or in the post-independence period—in environmental history and/or history of technology, or to simply transfer existing theoretical frameworks to new areas and times of study. We need to adjust our theoretical and method-

ological toolkit, perhaps even go back to the roots, and rethink the "big questions" once again: What is old and what is new? What is modern and what is traditional? What is natural and what is social? What is Western and what is non-Western? What is formal and what is informal? What is sustainable and what is wasteful? To answer these questions, historical research needs to become grounded in the daily realities of urban and rural life—in Africa and Asia as well as in Europe and North America. The labels "colonial" or "post-colonial," as Edgerton has critically remarked, do not axiomatically succeed in this endeavor. With a view to the fixation of many scholars in this tradition on Western technologies, he states that "[t]here is nothing subaltern about technologies in post-colonial literature" (Edgerton 2010: 696), calling for a "post-contextual" history of technology instead.[10] So the challenge might not merely be to "provincialize Europe," but to rethink technologies, infrastructures and environments in Europe first, before we make assumptions on their effect on the non-European world. In order to do so, introducing additional concepts like informality, creativity and hybridity as well as investigating processes like crafting, repairing and tinkering into historical studies of technologies and infrastructures might prove a promising and fruitful course (see e. g. Hård & Oldenziel 2013).

Second, investigating the infrastructural development in the Global South during colonialism and after independence, the Western narrative in which new infrastructure technologies are invented, negotiated, disseminated, and, after some time, disappear from the scene to become the invisible and silent foundations of everyday life soon reaches its limits. As we can see from the multitude of case studies discussed in this volume, most infrastructures in the Global South do not fit in this narrative, neither regarding the process nor its outcome. Instead of an evolutionary growth of technical systems towards universal access and provision, as expected when following the LTS approach, they reveal the racially and socially exclusive, contested, erratic and largely incomplete processes of planning, financing and building Western-style infrastructure in the (former) colonies. For understanding these processes, an in-depth analysis of actor networks, available resources (most of all knowledge), colonial identity politics, techno-capitalist "scale-making" (Goswami 2004: 49), and the specific social and natural environments in the colonies has proven more suitable than grand narratives of colonial subjugation, abstract notions of diffusion, macro-economic analyses, or models of the techno-economic rationale of system growth. As a consequence, concepts such as the LTS approach need to be critically re-evaluated, adapted and "enriched" to be of analytical use in (post)colonial contexts.

Third, as we have seen, infrastructure provision in the global South has developed a life of its own. Rather than regarding it as a deviation from the Western path, it deserves an analysis in its own right. While the "official" side of things—colonial policies and strategies—is relatively well-researched in the history of technology, the literature review for this issue has produced few studies that concentrate on how new technologies influenced everyday life in the colonies, on environmental juxtapositions, appropriation processes, and possible mixtures of "old" and "new" technologies (as called for by Hård & Jamison 2005; Edgerton 2007; or Arnold 2013). There are three aspects in particular that we should keep in mind here: First of all, the appropriation of technologies has never been equivalent with simply copying Western patterns of consumption. Secondly, what often determines the everyday life of infrastructures in the Global South is not only integrating new technologies but also keeping "old" infrastructures running. It is telling that aspects like repair and maintenance have been largely ignored in the history of infrastructures in the Global South—and even in the North—(for railways see Hurd & Kerr 2012: 48). And thirdly, formal infrastructures are only one of many ways for providing—and accessing—basic services in the Global South, and not necessarily the most appropriate ones. In most African, Asian and South American cities, for example, households without connection to the central water supply networks usually have the choice between a range of water service providers: tank trucks, pumping water for household storage tanks; neighbors with wells or access to the grid; shops offering canisters of water ranging from brackish (for flushing toilets) to drinking quality. Yet, these daily experiences of living in cities in the Global South have seldom informed academic research. It is only recently that planners and urban geographers have started to look at these "informal" modes of provision not only as symptoms of failure or crisis of "formal" infrastructures but as potentially (but of course not necessarily) more flexible, adapted, cost-effective and sustainable approaches—or simply the only way, for example for slum dwellers, to gain access at all (see e. g. Silver 2014; Terreni Brown 2014).

Finally, leaving behind Western-centered notions of technological development is not only vital for a better understanding of our past, but might also soon prove to be essential for grasping our immediate technological future, as present technological transfer processes have already begun to differ significantly from previous patterns. Current examples of South-South and South-North transfers of infrastructure services, for example, suggest that the North will lose importance as a point of departure for technological innovation and transfer. M-PESA, for example, a mobile phone-based banking, financing and microfinancing service launched in Kenya

in 2007 has not only expanded to Afghanistan, South Africa, India, but also to Eastern Europe in 2014 (Saylor 2012). And these potential turning points might prove vital in overcoming environmental lock-in processes as well, for example regarding resource use, in both the Global South and the West. For example, mass rural electrification by small, household-based solar systems took off in Bangladesh first, where four million systems had been installed by 2014 (Groh et al. 2016), setting an example not only for countries like Kenya or India, but also providing possible decentralized, sustainable solutions for realizing Europe's "green energy transition" (Kirchhoff et al. 2016). Challenging notions such as the LTS approach, the latter example also demonstrate that successful infrastructures do not only need to be provided by state, municipal, or large economic actors and financed by large international donors. They can also be built bottom-up without considerable economic or political resources by actors who have ample social capital and in-depth knowledge of the local needs and challenges. In teasing out these nuanced experiences of everyday life in the Global South (and North), as well as their implications for framing technology-society-environment-relations, an entangled history of technology, colonialism, and the environment might not only inspire new directions in these historical sub-disciplines, but, hopefully, also become more attractive to mainstream history as well.

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Endnotes

1 See for example, Wilson (2004); Lambert & Lester (2006); Howe (2010); Magee & Thompson (2010); Bennett & Hodge (2011); Peers & Gooptu (2012); Syriatou (2012).

2 See for example, MacLeod & Lewis (1988); Harrison (1994); Ramanna (2002); Anderson (2006); Mann (2007); Gandy (2008); McFarlane (2008); Peckham & Pomfred (2013).

3 See for example, Rao & Lourdusamy (2010); Winther (2011); Showers (2011); Shamir (2013); Kale (2014).

4 Interestingly, most studies tackling this area of study are not written by historians, but by urban geographers and anthropologists; see Beck (2009); Arnold (2013).

5 See for example, Crosby (1972); Shiva (1989); Beinart & McGregor (2003); D'Souza (2006); Beinart & Hughes (2007); Butlin (2009); Headrick (2010); Bennett & Hodge (2011).

6 For more complex counter-narratives, highlighting, for example, efforts for colonial nature conservation and sustainable resource management, the juxtaposition between colonial infrastructures, health, and environmental change, colonialism's role in the genesis of modern environmental awareness, or the interplay between scientific and indigenous environmental knowledge see: Groves (1995, 1997); Beattie (2011); Peckham (2015a), for an overview: Beattie (2012).

7 Cooper & Stoler (1997); Grove (1997); Arnold (2005); Hård & Jamison (2005); Edgerton (2007); Howe (2010); Bennett & Hodge (2011).

8 Sörlin and Warde emphasize a couple of trends of environmental history in general that mirror our diagnosis of colonial environmental history, namely a strong focus on rural issues with comparatively less work on urban (or suburban) environments, increasing interest in global transfer processes, a tendency to produce specialized case studies, as well as lacking recognition in the wider historiographical field. However, in contrast to Sörlin's and Warde's findings, colonial environmental history is a more coherent field with more shared themes, its core problem—colonialism's impact on and interrelation with the environment—more easily identifiable.

9 On the vast literature on water management, that is: irrigation, flood control, and sanitation, see Beattie & Morgan (2016); in particular: Whitcombe (1983); D'Souza (2006); Broich (2007); Beattie (2011); Carse (2014); Zeheter (2015); Peckham (2015b).

10 As an example, Edgerton mentions Prakash's claim that "to speak of India is to call attention to the structures in which the lives of its people are enmeshed—railroads, steel plants, mining, irrigation, hydro-electric projects [...] and now, the bomb." (Prakash 1999: 3) This long list, as Edgerton points out, refers almost completely to technologies from outside India.

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