ESSAYS

What are the most exciting horizons

for the History of Technology?

TECHNOLOGY, SOCIETAL CHALLENGES, AND GLOBAL SUSTAINABILITY HISTORY

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Interlacing disciplines

The field of history of technology has a long tradition of engaging with major societal issues and debates. Because of its name perhaps, some practitioners and most outsiders tend to associate the field with the study of histories *of* technology, aimed at mapping and explaining technological design and dynamics. That is indeed an important contribution, but it should not obscure the field's often-stated ambition to speak to wider societal concerns such as the dynamics and problems of industrial modernity, technological warfare, threats of worker deskilling and unemployment, empowerment of underrepresented social groups, colonialism, globalization, Europeanization, and much more. For in a technological age, major societal issues deeply entwine with technological change, and the historical investigation of such issues must bridge the humanities and the technical sciences, studying human history *and* technology as mutually constitutive.

That broad, long-standing, and widely shared ambition inspired what I find one of the most intellectually stimulating features of the field: repeatedly, it has bluntly refused to be yet another historical sub-discipline with technology as its neatly bounded subject matter. Instead, it has positioned itself as an interdisciplinary field of scholarship able to think about the relations between technology and society and culture in the broadest possible sense. "The nature of our subject matter requires an 'interlacing' of disciplines rather than a further 'fragmentation' of knowledge", Melvin Kranzberg emphasized in the context of the establishment of the Society for the History of Technology and its journal *Technology and Culture* in the late 1950s.[1] At that time, Kranzberg observed a "lack of personnel" trained to do such studies, but that problem has long gone. The field has since built a rich tradition of interdisciplinary and transdisciplinary interlacing – in micro-histories of specific socially situated innovation processes, in connecting such micro-studies to broader societal and historical debates, and in interacting with efforts to theorize and engage with sociotechnical change.

That interlacing ambition is extremely relevant today, in a context of widespread public and academic debate and concern about the proliferation of a vast array of

interrelated social and environmental crises – from climate change and other forms of environmental degradation to global inequality, terrorism, and pandemics to the threatened breakdown of unsustainable energy, mobility, food, financial, health, and urban systems. These debates prominently stage technology among the *causes* of these so-called 'global crises', 'grand challenges', or 'societal challenges'. Many also look to technology for *solutions* in the form of smart, sustainable and responsible innovation. Once again, the historical imagination is called upon to place these complex challenges, and the ambivalent roles of technology therein, in broader perspective. This requires connecting human history and technical change. In addition, the entwining of social and environmental challenges compels historians to interlace human and natural history – in a more systematic way than simply migrating into the field of environmental history. Such arguments have been made repeatedly in historiographical discussions on sustainability, the Anthropocene, and integrative humanities, also in this journal.[2] The intellectual challenge, of course, is how to do this.

This essay explores this inter- or transdisciplinary challenge of historically researching the entanglements of technology and social and environmental crises. As a point of departure, it sketches how present-day engineering communities discursively connect 'technology' to 'grand challenges' and 'history'. The essay then discusses how historians of technology may engage with such discourses, bringing into play scholarly insights from the existing literature, and briefly introducing the collective research effort of the pan-European research network *Tensions of Europe* to further investigate these issues. Finally, the essay probes the notion of a global sustainability history as one possible research avenue to historiographically interlace technology-related grand challenges that have often been addressed separately in economic, social and environmental history.

1   Melvin Kranzberg, 'At the start,' *Technology and Culture* 1, no. 1 (1959): 1, 7.

2   Robert Costanza et al., "Sustainability or collapse: what can we learn from integrating the history of humans and the rest of nature?" *AMBIO: A Journal of the Human Environment* 36, no. 7 (2007): 522-527; Helmuth Trischler, "The Anthropocene: A Challenge for the History of Science, Technology, and the Environment," *NTM Journal of the History of Science, Technology and Medicine* 24, no. 3 (2016): 309-335; Johan Schot, "Confronting the second deep transition through the historical imagination," *Technology and Culture* 57, no. 2 (2016): 445-456; Helmuth Trischler and Fabienne Will, "Technosphere, Technocene, and the History of Technology," *Icon* 23 (2017): 1-18; Maria Paula Diogo, Ivo Louro, and Davide Scarso, "Uncanny Nature: Why the concept of Anthropocene is relevant for historians of technology," *Icon* 23 (2017): 27-38; Sverker Sörlin, "Reform and responsibility – the climate of history in times of transformation," *Historisk tidskrift* 97, no. 1 (2018): 7-23.

Histories of technology and grand challenges

A first and tentative historical study of technology and societal challenges stems from historians interacting with engineering visionaries and students. Let me therefore start by briefly considering current engineering discourses on this subject.

In the last decade or so, engineering communities have become extremely vocal about the power of innovation to solve major problems of our time. "People face a host of global challenges that must be addressed through long-term and innovative education, research, and engineering solutions", observed the presidents of the U.S. National Academy of Engineering, the UK Royal Academy of Engineering, and the Chinese Academy of Engineering in a recent joint manifesto. The three academies organized and promoted the translation of humanity's challenges into *Grand Challenges for Engineering*, a research agenda identifying breakthroughs that engineers should work on so that "human life as we know it can continue on this planet."[3] This call to arms has been widely adopted in engineering research and education programs worldwide.

Next to 'technology' and 'global challenges,' history plays a pivotal role in this discourse. The three academy presidents note that engineering can credibly promise to provide solutions to humanity's current crises because engineering has solved problems of a similar magnitude in the past – feeding and sheltering over seven billion people, for example. Another version of the argument is that past technologies *caused* today's problem (e.g. the historical development of energy and mobility systems triggered the climate change challenge), and since technology is part of the problem, it also holds the key to the solution.[4] Either way, this well-intended yet self-interested engineering discourse to save the planet through innovation connects 'technology' to 'global challenges' and 'history,' but in such a way that it tends to monopolize the problem definition and the articulation of solutions, silencing alternatives and risking tunnel vision. Professional historians' reflection on the relationship between technology, societal challenges, and history is urgently needed.

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3   C.D. Mote, Ann Dowling, and Ji Zhou, "The Power of an Idea: The International Impacts of the Grand Challenges for Engineering," *Engineering* 2, no. 1 (2016) 4-7. See also: *Global Grand Challenges. A Report of the 2013 Summit* (The Institution of Engineering and Technology, 2013); http://www.engineeringchallenges.org/ (accessed 24 Jan 2019).

4   Rutger van Santen, Djan Khoe, and Bram Vermeer, *2030: Technology that will change our world* (Oxford, 2010). Also: Rutger van Santen, Djan Khoe, and Bram Vermeer, *The thinking pill and other technology that will change our lives* (Amsterdam, 2007).

It is this discourse that inspired the writing of a first, broad-strokes history of technology and societal challenges, largely based on existing history of technology scholarship.[5] Two sets of insights from that exercise seem particularly relevant when engaging with, and scrutinizing, the reigning engineering discourse.

Firstly, present-day engineering community spokespersons seem to be correct in assuming that technology and engineering have a long track record of engaging with 'global challenges.' Since the early nineteenth century at least, an increasing number of visionaries and social groups saw novel technology as the means to solve major challenges to clothe, feed, shelter, and lift out of poverty large populations and to democratize energy and transport access. Indeed, the promise of solving such challenges was a major legitimation for the establishment of engineering as a civil profession and scientific discipline and has shaped its development ever since. However, engineering community spokespersons err in portraying technological responses to 'global challenges' as univocal, straightforward, and unproblematic. Different social groups – policy makers, entrepreneurs, user groups, different groups of engineers and other technicians – articulated very different problem definitions and solution proposals. Accordingly, they took technology and its societal implications in many different, often contradictory, directions, for better and worse.

To mention just one example: in the 1830s visionary engineers embraced the novel railway technology to solve key societal challenges such as endemic war, mass poverty, and the tyranny of nature. Rail connections, they argued, would inspire peaceful and prosperous exchanges of scarce resources and civilized ideas across class, national, and geographical boundaries. That promise was subsequently embraced, copied, and hijacked by many. National, urban and colonial governments cited it when building railways and other infrastructure to develop, benefit, integrate, control or subjugate their territories and constituencies. Investors and entrepreneurs looked to railways to solve existing corporate problems and develop new business opportunities (which, amongst others, initiated the rise to dominance of large tech firms in the modern business landscape). Various user and non-user groups developed new practices of play, tourism, livelihood, empowerment, mass migration, social differentiation, or political resistance in response. Militaries appropriated railways to increase defensive and offensive capabilities, and railways became deeply implicated in two World Wars. Terrorists found in railways a new and highly promising high profile target. In short, these and many other historical actors took

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5   Erik van der Vleuten, Ruth Oldenziel, and Mila Davids, *Engineering the Future, Understanding the Past. A Social History of Technology* (Amsterdam, 2017).

the new technology and its social and environmental implications in many different directions, lifting large populations out of absolute poverty but also enabling unprecedented mass violence, destruction, inequality, and – as the human-built world expanded along its infrastructural arteries – ecosystem fragmentation.[6] Thus, when examining the role of technology in past and present crises, a first major historical research challenge is to scrutinize who defined what the 'grand challenges' and technical and non-technical solutions were at any given time. Which historical actors took these promising solutions into what real-life practice? And how did these many actors, problem definitions, and solutions jointly create multiple, ambivalent, and often unpredictable historical outcomes?[7]

A second set of historical insights on technology and societal challenges pertains to the engineering community's long history of being reflective about the above-mentioned complexities. The continuing resurfacing of discourses promoting innovation as the unproblematic solution to societal challenges should not blind us to the history of attempts to anticipate technology's potentially harmful implications. Certainly by 1945, technology's potential to co-produce unexpected harm and suffering had been abundantly highlighted in two world wars, many smaller ones, and the Great Depression. Among the many historical agents proposing to coordinate, control and anticipate technology's social and environmental implications, engineering communities developed all kinds of strategies to steer technology into more beneficial directions and avoid harmful futures.[8]

The reflective strategies of engineering also include technocratic innovation – even though counterculture criticasters would later strip the technocracy concept from its reflective layers and blame it for much wrongdoing. It was in the context of the Western world's thirty-years crisis (1914-1945) that the technocracy movement called upon scientists, engineers and other experts to wrestle control over technology from politicians and business leaders. The latter groups, allegedly driven by ideology, power struggles and profit maximizing, had steered technology towards global war,

6   Per Högselius, Arne Kaijser, and Erik van der Vleuten, *Europe's infrastructure transition: Economy, war, nature* (London/ New York, 2015); Maria Paula Diogo and Dirk van Laak, *Europeans Globalizing: Mapping, Exploiting, Exchanging* (London/ New York, 2016); Ruth Oldenziel and Mikael Hard, *Consumers, tinkerers, rebels: The people who shaped Europe* (Houndmills, 2013), especially 83-123.

7   Erik van der Vleuten, "Radical change and deep transitions: Lessons from Europe's infrastructure transition 1815–2015," *Environmental Innovation and Societal Transitions*, doi.org/10.1016/j.eist.2017.12.004.

8   Also: Thomas P. Hughes, *Rescuing Prometheus* (New York: Pantheon Books, 1998).

worker exploitation, and economic collapse. Engineers, architects, scientists, planners and other experts, by contrast, so it was argued, would deploy scientific methodology to seek more socially beneficial and just courses of technology development.[9] For example, postwar sociotechnical ("man-machine interaction") systems-thinking offered a set of methods to define problems and solutions, model and simulate possible futures, and thereby identify and anticipate potential future harm. Think e.g. of Jay Forrester and the MIT computing lab's modelling and simulating of industrial, urban, and world problems (including the famous Club of Rome report *Limits to Growth* of 1972) explicitly challenging political and business leaders' short-term thinking and developing alternative, more beneficial courses of action. Today, complex systems-approaches figure prominently in engineering approaches to analyzing grand challenges and innovation solutions.[10]

It is also telling that, as part and parcel of technocratic responses to social challenges, postwar engineers were urged to become more reflective and responsible: humanities and social science courses were structurally included in engineering education; an engineering ethics was developed that emphasized public values instead of loyalty to employers or simply making things work; and international expert-organizations were established as a counter-weight to political fragmentation and strife.[11] The postwar institution-alization of the field of history of technology, too, related to this sense of mission (training more reflective engineers and connecting experts from East and West to mitigate political Cold War tensions, for example).[12]

Participative innovation, as an alternative set of strategies to rescue technology from its potentially harmful effects, aims for the same goals using different means. When 1960s and 1970s counterculture debaters found that 'responsible engineers' had not prevented technology's implication in domestic human rights violations, the

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9   "What is technocracy," *Technocrat* 3, no. 4 (1937): 3.

10 Van Santen, *2030*.

11 E.g. Agatha C., Hughes, and Thomas P. Hughes (eds.), *Systems, experts, and computers: The systems approach in management and engineering, World War II and after* (MIT Press, 2000); Gary Lee Downey, Juan C. Lucena, and Carl Mitcham, "Engineering ethics and identity: Emerging initiatives in comparative perspective," *Science and Engineering Ethics* 13, no. 4 (2007): 463-487; Carl Micham, "A historico-ethical perspective on engineering education: From use and convenience to policy engagement," *Engineering Studies* 1, no. 1 (2009): 35-53.

12 Bruce E. Seely, "SHOT, the history of technology, and engineering education," *Technology and Culture* 36, no. 4 (1995): 739-772; Angus Buchanan, "From Cold War Peacemakers to Environmental Crusaders: The Development of ICOHTEC over Forty Years," in *ICOHTEC International Committee for the History of Technology 1968–2008*, edited by Wolfgang Weber (Bochum, 2009).

Vietnam War and environmental degradation, the humanizing technology movement in engineering gave all kinds of stakeholders access to technological decision making and the innovation process. The argument was that those affected by new technology knew the implications of the new technologies for their lives better than experts speaking on their behalf. Thus followed the 'science shop' and 'appropriate technology' movements; participative technology assessment and citizen conferences; user-centred and participative design and all sorts of user-innovation; and the rise of Science and Technology Studies (STS) as the scholarly field to strengthen and critically reflect on these issues. Again, the history of technology was involved too. In countries such as the Netherlands, for example, the field emerged in the 1970s to historically demonstrate that technology was socially situated, indicating that contested technologies such as automation and nuclear power could in principle be influenced and steered towards democratic and human values.[13]

Today it is acknowledged that both technocratic and participative approaches to rescue technology from possible harmful effects have had their pros and cons. Both offer tools to identify potentially harmful futures. And both can be hijacked by corporate or political interests, among others. Either way, there is no doubt that engineers have a long tradition of reflection on, and attempting to anticipate, potentially harmful effects of innovation. The present-day challenge for historical research is not to promote the one strategy or the other, but to research and scrutinize the historical development and selection of approaches for reflecting on, and governing, the relationship between technology and societal challenges. Which and whose strategies have been prioritized in the past? How were they put into action, and how did that work out?

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If anything, this first and rudimentary study of the history of technology and societal challenges based on existing literature shows that there is much to be researched. Can and should we proceed and develop historical analyses and narratives of the multiple entanglements of technology and specific crisis domains such as environmental, financial, migration, energy, urban, health, and security challenges? How can we study the *interrelationships* between such crises that Ulrich Beck and others have highlighted?[14] How should we study crises as simultaneously imagined

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13   Matthew H. Wisnioski, *Engineers for change: Competing visions of technology in 1960s America* (MIT Press, 2012); Van der Vleuten, et al., *Engineering the future*, 131-161; Erik van der Vleuten, "Techniekgeschiedenis en maatschappelijke transities," *Ex Tempore* 37, no. 3 (2018): 194-212.

14   Ulrich Beck, *World at Risk* (Cambridge: Polity Press, 2009).

(in media discourses for example) and real – in terms of specific effects on the lives of specific people? What about the simultaneously local and global dynamics of the technology-crises relationship? And as several colleagues have pressed for, and rightly so, can we investigate these issues historically in a meta-language that (unlike the study presented above) does not take present-day engineering discourse as a privileged point of departure?

It is these and others questions that the *Tensions of Europe* research network set out to explore a few years ago.[15] In 2015, when the new program was formally announced, that research network was just about to conclude its previous research program, a two-decade long research effort into the historical roles of technology in European integration and fragmentation (one of the major public and academic issues of the 1990s and 2000s, which today has morphed into yet another crisis debate). That research effort had demonstrated how a transnational and inter-disciplinary historical community could jointly produce novel historical narratives of technology and European integration, shifting the focus of European integration history from political processes to a broad range of technology actors, processes and practices greatly affecting European identities and everyday life from the early nineteenth century onward.[16] Experienced in researching the ambivalent roles of technology in a major societal transformation, that community should be able to make historical sense of the current confusion regarding the proliferation of global crises and the roles of technology therein.

In order to explore the possibilities of such a new collaborative research effort, a number of working groups started building thematic networks and research agendas, discussing what questions are relevant and how they might be answered.

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15   Erik van der Vleuten, "Challenging Prometheus: a history of technology for an age of grand challenges." (Technische Universiteit Eindhoven, 2017). See also https://www.tensionsofeurope.eu/second-flagship-program-technology-societal-challenges/ (accessed 30 Jan 2019).

16   Thomas J. Misa and Johan Schot, "Introduction: Inventing Europe: Technology and the hidden integration of Europe," *History and Technology* 21, no. 1 (2005) 1-19; Erik van der Vleuten, "Toward a transnational history of technology: meanings, promises, pitfalls," *Technology and Culture* 49, no. 4 (2008): 974-994; Arne Kaijser, "The Trail from Trail: New Challenges for Historians of Technology," *Technology and Culture* 52, no. 1 (2011): 131-142. The synthesis book series consists of: Oldenziel and Hard, *Consumers, tinkerers, rebels;* Martin Kohlrausch and Helmuth Trischler, *Building Europe on expertise. Innovators, organizers, networkers* (London/ New York, 2014); Wolfram Kaiser and Johan W. Schot, *Writing the rules for Europe: experts, cartels and international organizations* (London/ New York, 2014); Högselius et al., *Europe's infrastructure transition*; Diogo and van Laak, *Europeans Globalizing*; Andreas Fickers and Pascal Griset, *Communicating Europe: Technologies, Information, Events* (London/ New York, 2019).

In the past three years or so that effort has involved over two dozen workshops and conferences and a growing number of international networking and research grants. This is not the place to discuss these research agendas; several of these will be published shortly.[17] Rather, in the context of this essay, it is important to observe that while this novel research effort is bearing fruit, it currently faces at least two major challenges. First, as an outgrowth of a Europe-based research network, its participants are overwhelmingly Europe-based too, even though all agree that present-day societal challenges are *global* crises, and that their investigation requires cross-continental research networks to avoid reproducing Eurocentrism. It is therefore crucial to connect to other research communities.

Second, how can we connect and meaningfully add-up thematic historical research efforts on societal challenges such as the energy, resource, migration, security, biodiversity, or urban mobility challenges, jointly producing a major intervention with present-day historical and public debates on societal challenges? This leads us back to Kranzberg's notion of the history of technology as an interdisciplinary discipline and the question of how to interlace different historical literatures across the divides of historical specialization.

Global sustainability history

In order to address this question, I want here to probe into the recent literature on 'sustainability history', which I find interesting because it promises to interlace the study of challenges and crises often studied separately in economic, social, and environmental history.

Notably, the notion of 'sustainability' is but one of several synthesizing concepts that historians are presently examining in order to draw different social and environmental crises into one-and-the-same historical narrative and analysis. These concepts typically sprang from specific crisis domains, but were subsequently expanded to historically study a broader variety of crises. For example, historical Anthropocene research first highlighted the historical caesura of anthropogenic climate change, then broadened to consider all sorts of environmental impacts of human activity and technology, and currently seeks to rethink the history of nature

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17   Erik van der Vleuten, "History and Technology in an Age of Grand Challenges: Raising Questions. Guest editor's introduction"; Matthias Heymann, et al., "Challenging Europe: Technology, Environment and the Quest for Resource Security"; Ute Hasenöhrl and Jan-Henrik Meyer, "The Energy Challenge in Historical Perspective"; Frank Schipper, et al., "Sustainable Urban Mobility in the Present, Past, and Future"; Stathis Arapostathis and Leonard Laborie, "Governing technology in the age of grand challenges"; Karena Kalmbach, et al., "Crises and Technological Futures – Historical Perspectives." *Technology and Culture* (forthcoming).

and humans and its many conflicts and crises in an integrated way. Another example is historical research on security crises, which gained a research boost from the 21th century surge in international terrorism. That research tapped into the concept of 'securitization' that political scientists had developed to study the discursive (un)making of security crises beyond military security, including not only terrorism but also food and energy security, ecosystem damages, pandemics, mass migration, unmanageable urbanization, and so on. A third example is the 2008 financial and debt crisis, which, Jürgen Kocka and Marcel van der Linden observe, fuelled the comeback of 'capitalism' as a synthetic and analytical historical crisis concept. Whether rooted in (and carrying analytical legacies from) the study of environmental, international relations or economic crises, historians now use these concepts for a broader historical analysis and synthesis of our present-day cavalcade of crises.[18] If I here probe the notion of sustainability history, it is because that emerging literature explicitly claims to connect challenges traditionally studied in economic, social, and environmental history without *a priori* privileging one of these fields.

Considering the high-profile political and public discussions of sustainability since the 1980s, and the appearance of sustainability history work since the 1990s, it is remarkable that the institutionalization of sustainability history is of a rather recent date. In 2015, Jeremy Caradonna reviewed the nascent field, criticized its poor academic institutionalization, and proceeded to edit the *Routledge Handbook of the History of Sustainability* ("give me a handbook and I will raise a field"[19]).[20] His view

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18   E.g. Jason W. Moore, ed., *Anthropocene or Capitalocene? Nature, History, and the Crisis of Capitalism* (Oakland: PM Press, 2016); Christophe Bonneuil and Jean-Baptiste Fressoz, *The shock of the Anthropocene: The Earth, history and us* (Verso Books, 2016); Barry Buzan et al., *Security: a new framework for analysis* (Lynne Rienner Publishers, 1998); Eckart Conze, *Die Suche nach Sicherheit. Eine Geschichte der Bundesrepublik Deutschland von 1949 bis in die Gegenwart* (*The search for security. A History of the Federal Republic of Germany from 1949 to the Present*) (München, 2009); Cornel Zwierlein and Beatrice de Graaf, "Security and conspiracy in modern history," *Historical Social Research* (2013): 7-45; Beatrice de Graaf and Cornel Zwierlein, " Historicizing security-entering" the conspiracy dispositive," *Historical Social Research* (2013): 46-64; Jürgen Kocka and Marcel van der Linden, eds., *Capitalism: The reemergence of a historical concept*, (Bloomsbury Publishing, 2016); Jürgen Kocka, *Capitalism: A short history* (Princeton University Press, 2016).

19   Ultike Felt, Rayvon Fouché, et al., eds., *The handbook of science and technology studies. Fourth edition* (MIT Press, 2016), 2 for a reflection of role of handbooks in scholarship.

20   Jeremy L. Caradonna, "The Historiography of Sustainability: An Emergent Subfield," *Economic- and Ecohistory* 11, no. 1(2015), 7-18; Jeremy L. Caradonna, ed., *Routledge Handbook of the History of Sustainability* (Routledge, 2017). For a sustainability history of ideas: Ulrich Grober, *Sustainability: A cultural history* (Green Books, Cambridge 2012); Jeremy L. Caradonna, *Sustainability: A history* (Oxford University Press, 2014).

of the field explicitly mobilizes the synthetic connotations of the sustainability concept: mimicking the political sustainability concept's juxtaposition of economic, social, and environmental sustainability, he argues that "the challenge of writing the history of sustainability is to find *linkages* between environmental thought and practices, economic policy, and social wellbeing [emphasis added]."[21] Caradonna insists that the field is equally interested in economic performance, social justice and wellbeing, and the natural environment; it explicitly rejects the prioritizing of either economic, social, or environmental history, to which the new field is greatly indebted and on which it builds. However, the new handbook is rather vague about how the "linkages" between economic, social and environmental sustainability can be historically researched, except for investigation of their discursive combination in histories of the sustainability idea and the social movement associated with that idea.

Hitherto unrelated to this recent handbook initiative, several working groups in the above-mentioned *Tensions of Europe* technology and grand challenges program speak to this multi-dimensional notion of sustainability history. For example, the working group on urban sustainable mobility takes present-day urban sustainability challenges as its point of departure.[22] It then uses the sustainability framework in terms of environmental (e.g. cleaner air), economic (e.g. affordability), and social justice (access for all) perspectives to revisit the conflicted histories of private automobility, non-motorized mobility (cycling, walking), and public transport. In this case, the local unit of analysis – the city – facilitates the integration of economic, social, environmental, and technological mobility histories into coherent historical narratives. Another working group historicizes the present-day discourses on energy challenges and transitions, combining environmental and social history approaches to historicize sustainable energy technologies, the current unsustainable energy system, and agents and discourses of change.[23] Both of these initiatives, however, focus on individual crises domains, the mobility and energy challenge respectively.

By contrast, a third working group set out to develop the notion of global sustainability history in order to connect different crisis domains and scales into one and the same historical analysis and synthesis.[24] That program's integrative use of

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21   Caradonna, "The Historiography of Sustainability", 10.

22   Schipper, "Sustainable Urban Mobility"; Ruth Oldenziel and Helmuth Trischler ed., *Cycling and Recycling: Histories of Sustainable Practices* (München, 2015); Ruth Oldenziel et al. eds., *Cycling Cities: The European Experience: Hundred Years of Policy and Practice* (Eindhoven, 2016). For historical sustainability policy studies of specific cities, see http://www.cyclingcities.info/your-city-next/ (last consulted 1 February, 2019).

23   Hasenöhrl and Meyer, "The Energy Challenge."

24   https://www.tensionsofeurope.eu/global-resources-and-sustainability/ (accessed 1 Feb 2019).

the sustainability concept is rooted in a recent sustainability history of the Netherlands since 1850, in which economic historians and historians of technology developed a broad notion of sustainability that provides the gridlines for a narrative of the coming and going of manifold crises of industrial modernity.[25] That history builds on the elaborate sustainability indicator set endorsed by the statistical offices of such organizations as the UNECE, OECD, and EU.[26] Methodological issues of quantification and methodological nationalism aside, this sustainability framework structures an unfolding qualitative narrative of historical actors articulating and prioritizing economic, social and environmental problems and (often technological) solutions, from omnipresent nineteenth century poverty concerns to "the social question" and housing, food, energy and public hygiene challenges to issues of biodiversity and pollution. Doing so, the study identifies *linkages* between economic, social and environmental (un)sustainable developments (1) synchronically, in historical discourses and (often technological) social action; and (2) diachronically, in the long-term results of those actions, which produced long-term trade-offs between different sustainability indicators (increasing income, equality, schooling and health at the expense of decreasing biodiversity and air quality, for example).

Like the studies in Caradonna's sustainability history handbook, the latter study has examined (un)sustainability history within the spatial bounds of the nation-state. Sustainability history, however, also needs to account for the multiple and entangled scales on which crises and sustainability issues unfold. A particularly urgent challenge, it seems to me, is to study the sustainability histories of the Global South and North as entangled and mutually shaping. In scholarship on contemporary sustainability issues, the relevance of global sustainability connections has been highlighted in the Foreign Direct Responsibility and sustainability telecouplings literatures. For several decades, the Foreign Direct Responsibility literature has studied the moral and legal accountability of multinational companies in their Western home jurisdictions for alleged damages overseas. For example, the court cases and out-of-court settlements involving Royal Dutch Shell and oil spills in the Niger delta caused by its Nigerian subsidiary spotlights transcontinental social and environmental sustainability entanglements. The more recent literature on

25   Harry Lintsen, et al., *Well-being, Sustainability and Social Development. The Netherlands 1850-2050* (Springer, 2018); Frank Veraart, "Land or lakes: Gravel excavation in Dutch spatial and resources policies through the lens of sustainability developments, 1950–2015," *Land use policy* 82 (2019): 367-374.

26   UNECE, *Conference of European Statisticians Recommendations on Measuring Sustainable Development* (Geneva, 2014); Niels Schoenakers, et al., "Comparison of Measurement Systems for Sustainable Development at the National Level," *Sustainable Development* 23, no. 5 (2015): 285–300.

sustainability telecouplings calls for the systematic investigation of interrelated environmental and socioeconomic interactions across vast distances; that literature, too, operates on the assumption that that low-income countries bear the social and environmental sustainability cost for the economic sustainability gains of high-income countries.[27] A global sustainability history could unpack and scrutinize the historical dynamics and implications of such entanglements, combining a multi-dimensional and a global approach to sustainability history.

As such, global sustainability history can draw on three decades of global and transnational history examining the historical interconnectedness of societies.[28] In particular, it can draw on the transnational turn in the historiography of infrastructure and supply chains, and take transcontinental resource chains as its unit of analysis.[29] The above example of post-war entanglement of (un)sustainability developments in the Niger delta and the Netherlands (particularly the Rotterdam harbor area, a key European oil and petrochemical industry hub) through Shell's global oil infrastructure was not a simple matter of Global South stakeholders bearing the costs and Global North stakeholders dividing the spoils. An explorative multi-dimensional sustainability history of this case suggests that as both economies transitioned to oil, both encountered vast environmental problems, and both experienced vast economic growth – though in terms of socioeconomic inequalities the two oil-connected sites developed notoriously differently. Such historical study of sustainability's different dimensions and many sub-categories may produce a more nuanced and fine-grained understanding of globally entangled sustainability history for this and other cases.

27   Julio Faundez and Celine Tan, "International economic law, natural resources and sustainable development," *International Journal of Law in Context* 11, no. 2 (2015): 109-112; Celine Tan and Julio Faundez eds., *Natural resources and sustainable development. International economic law perspectives* (Cheltenham UK: Edward Elgar, 2017); , Liesbeth Enneking, "The Future of Foreign Direct Liability: Exploring the International Relevance of the Dutch Shell Nigeria Case," *Utrecht L. Rev.* 10 (2014): 44; Cees de Groot, "The 'Shell Nigeria Issue': Judgments by the Court of Appeal of The Hague, The Netherlands," *European Company Law* 13, no. 3 (2016): 98-104; Jianguo Liu et al., "Framing sustainability in a telecoupled world," *Ecology and Society* 18, no. 2 (2013); Vanessa Hull and Jianguo Liu, "Telecoupling: A new frontier for global sustainability," *Ecology and Society* 23, no. 4 (2018).

28   Akira Iriye, *Global and Transnational History: The Past, Present, and Future* (London: Palgrave MacMillan, 2013); Pierre-Yves Saunier, *Transnational history* (Palgrave Macmillan, 2013).

29   Högselius, *Europe's infrastructure transition*; Per Högselius et al. eds., *The making of Europe's critical infrastructure: Common connections and shared vulnerabilities* (Palgrave, 2013); Gabrielle Hecht, *Being nuclear: Africans and the global uranium trade* (MIT Press, 2012); Gabrielle Hecht, ed., *Entangled Geographies: Empire and Technopolitics in the Global Cold War* (MIT Press, 2011).

Crucial historical research questions would include which historical actors – e.g. the supply chain actors (Royal Dutch Shell in the above example) and companies, workers, locals, NGO's, different levels of government at multiple sites along the resource infrastructure - had what influence on which economic, social, and environmental (un)sustainability dynamics and inequalities along global supply chains.[30]

Such a global sustainability history, however, is only in its infancy. The proof of the pudding, as always, will be in the eating. The sustainability concept clearly has potential to interlace many sorts of crises into one analysis and narrative, but several pitfalls to this line of investigation are discernible from the outset. These include the risk of reproducing nation-centred history (if only because most historical sustainability statistics are country-based) and of reproducing Eurocentrism (assuming that sustainability telecouplings only count if the Global North is involved; studying South-South entanglements is therefore an important antidote). Also, translating the policy concept of sustainability into a historical concept involves an eminent danger of projecting associated Western meanings on global issues. A multi-sited research design that lends voice to multiple actors connected through the resource chain will be of crucial importance, as will historical research questions on the knowledge politics of sustainability (history)[31]: How do Western-based sustainability history gridlines compare to non-Western history gridlines? How does sustainability history as measured through the lens of present-day sustainability monitors compare to sustainability history as experienced by multiple historical stakeholders? Whose sustainability knowledges prevail and whose are ignored in historical and present-day knowledge production, including our own sustainability history endeavour?

<p align="center">*   *   *</p>

These questions on global sustainability history lead us back to the more general research challenge raised in this essay. If the history of technology has the ambition and the experience to research interlacings between and beyond many historical subdisciplines, how can that experience be put to work in order to historically inquire

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30   Veraart, et al., "Connected by oil: The entangled sustainability histories of Nigeria and the Netherlands, 1950-2015," *The Extractive Industries and Societies* (forthcoming).

31   On sustainability knowledge politics: E. de Hoop, E., et al., "Smart urbanism in Barcelona: a knowledge politics perspective," in *The Politics of Urban Sustainability Transitions: Knowledge, Power and Governance*, edited by Jens Jensen, et al. (Routledge, 2018); Evelien de Hoop and Saurabh Arora, "Material meanings: 'waste' as a performative category of land in colonial India," *Journal of Historical Geography* 55 (2017): 82-92.

the relationships between history, technology, and a great variety of global crises? What are the opportunities and pitfalls involved in such a research endeavour? In this context I find the questions raised on the politics of knowledge production particularly salient. Whose knowledges on societal challenges and solutions have been historically prioritized or sidelined? What were the consequences, and for whom – across social groups, across generations, across geographies, and across species? How can historical research today avoid reproducing knowledge asymmetries and inequalities, and engage reflectively with such knowledge politics that is inherent (and, still, too often implicit) in historical research as much as in any other research?

These reflexivity questions, in my view, belong to the grand challenges of the field of history of technology today. To quote from the engineering discourse on technology and societal challenges one last time: in the face of today's global challenges, the world needs "creativity, innovation, passion, and sheer intellectual horsepower."[32] That should apply not only to the engineering of solutions, but surely also to the reflective historiographical engagement with the big questions of our times.

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32   Sir John Parker (then President of the Royal Academy of Engineering) in *Global Grand Challenges*, 2.

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