

INTRODUCTION

Entangling Technological Infrastructures, Material Flows and Environmental Modernities

Stathis Arapostathis and Frank Veraart

Guest Editors

In this special issue, we explore the sociopolitical entanglements of different technological systems and the way that this affects, in different places, patterns of well-being, of economic and environmental development, and emergent concerns about sustainability. By studying the entanglement of technological systems and understanding processes of linking and de-linking of sociotechnical systems from extraction to the end use, the special issue unravels and historicizes the environmental impact, degradation, and construction of new “natures.”¹ The contributions within it concern pertinent material across many scales, addressing connections between the local development of these “natures” and transnational and globalizing material, as well as flows of financing, knowledge, and patterns of development. In contrast to the recently published entanglement histories of American–South Asian relations, which a focus on recasting the position of the USA within global narratives,² contributors to this special issue take entanglements from a multitude of regions and contexts in Europe and beyond. They aim to link histories of environment and technology with those of politics and economy, and heeding the contemporary historiographic call for transdisciplinary approaches. This issue addresses the following questions: How did the entanglement of technological infrastructures engender the domination and exploitation of nature while at the same time increasing sociotechnical complexities and vulnerabilities? How has the historic pursuit of technological innovation and transformation by companies, technocrats, and politicians contributed to the creation of technological and ecological crises and how did the distribution of economic, environmental, and social costs and returns develop over time? How have these developments shaped transnational and (post)colonial relationships and global North–South interactions?

¹ Jørgensen et al., *New Natures*.

² Fischer-Tiné and Slate, *The United States and South Asia from the Age of Empire to Decolonization*.

This special issue is the joint outcome of two research projects, one in Greece and one in the Netherlands. The Greek project, entitled “Configuring Environment and Food: Critical Technoscientific Networks and the Agri-food sector in Greece 1950–2017” (CONEF, www.conef.gr), has been funded by the Hellenic Foundation of Research and Innovation (HFRI, Ref. no. 2451). The Dutch project, funded by Dutch Research Council NWO, is entitled “Global Resources and Sustainability of European modernization, 1820–2020 (GREASE).” The articles in the present collection have grown from three workshops organized by the guest editors: two that were part of their aforementioned projects within the Tensions of Europe conferences (www.tensionsofeurope.eu) of 2021 and 2022, and the third being the international conference organized by the Greek project CONEF on “Agrifood Policies as Science and Technology Politics since 1850: Knowledge, Environment, Society” (24–26 September 2021).

Technological Modernities and the Transnational Turn

Since the nineteenth century, industrialization and modernization have driven an increasing demand for raw materials within Europe. Industrial production and transport systems allowed materials to be acquired, processed, consumed, and disposed of in geographically distinct and distant places. The networks of material flows created by industrialization also gave way to differentially configured local economies in the distinct places they passed through, altering local social, political, and cultural dynamics. Social scientists and historians of technology have studied the social, political, and institutional constructions of large-scale technological systems. The influential work of Thomas Hughes has set the canon for the historiography of technology and the social constructivist approaches which understand technology not as an object but as a system. Hughes understands technology as a system that develops from (1) invention to (2) research and development, followed by (3) its expansion into a system with “universal characteristics,” propelled by increasing technological momentum.³ Instances of technological problems and bottlenecks in the process of the evolution and expansion of the system are considered as reverse salients that shape the conditions of its technological and sociopolitical adaptation. Hughes’ work on the *American Genesis* enhanced his approach further by arguing the importance of technological transformation in the industrialization of major Western countries, societies, and economies like the US.⁴ Historians of technology have built on Hughesian historiography to analyze the emergence and development of large-scale electricity and transportation networks at regional,

³ Hughes, *Networks of Power*.

⁴ Hughes, *American Genesis*.

national, and transnational levels and sociopolitical settings. In the 1980s and 1990s, Hughes' systems approach set the historiographic paradigm for historians of technology, bolstered by its affinity to the then emerging field of sociology of technology and the social construction of technology. The analytical framework of large technological systems was appropriated in several aspects by sociologists employing the social construction of technology (SCOT) and actor network theory (ANT) approaches.⁵

Technological history is now routinely argued by historians of technology as crucial to understanding modernity. Modernity is not only defined by industrial transformations but is also, and perhaps especially, defined by technological transformations. European modernities have been the result not only of major political and economic events and crises, but by material and political entanglements across regions, entanglements that boosted the ideology of technological determinism. Large-scale technological infrastructures, such as energy and transportation networks, have come to define a vision of seemingly endless progress achieved through the human assertion of power over the forces of nature. Mundane technologies of consumption, however, have shaped and defined notions of well-being and comfort. They came to be associated with the identities of social groups in frequent possession of them, imbuing those groups and their members with a kind of social capital springing from an association with the modern values of comfort and progress. They boosted capitalist ideologies of endless prosperity and growth. Historians, sociologists and anthropologists of technology have stressed the affectual allure of technological infrastructures.⁶ Historian Rudolf Mrázek approaches infrastructures by studying the “enthusiasm of the imagination,”⁷ meaning the imaginaries and promises that were articulated around technologies and widely spread across different populations. David Nye, historian of technology and American culture, has shown that technologies of energy or transportation can be imagined as artifacts for the emancipation of society, its domination over nature, and its organization based on the unimpeded circulation of material and human capital.⁸ Technologies and technological infrastructures can also be part and parcel of what anthropologist Dimitris Dalakoglou has dubbed

⁵ Hughes, “The Evolution of Large Technological Systems,” 51–82; Bijker, *Of Bicycles, Bakelites, and Bulbs*; Bijker and Law, eds., *Shaping Technology/Building Society*; Bijker et al., *The Social Construction of Technological Systems*; Bowker and Star, *Sorting Things Out*; Edwards, *The Closed World*; Edwards, “Infrastructure and modernity;” Hecht, *Entangled Geographies*; Latour, *We Have Never Been Modern*; *Reassembling the Social*; *Aramis, or the Love of Technology*; Latour, *Science in Action*.

⁶ Larkin, “The Politics and Poetics of Infrastructure,” 327–43.

⁷ Mrázek, *Engineers of Happy Land*.

⁸ Nye, *Electrifying America; American Technological Sublime*.

as “infrastructural fetishism.” In this context they are presented and imagined as key objects for participating in a shared, common, dominant, and unavoidable paradigm of modernity.⁹

Transnational historiography of technology shows the technopolitical function of technologies and technological infrastructures. It succeeds a tradition of scholarship in history and sociology of technology that promoted the concept of techno-politics as a critical concept for the study of the interaction of technology and society. Technologies are studied as tools for the organization of territories and populations, key materialities that determine socioeconomic and sociopolitical orders.¹⁰ Technological infrastructures are assemblages of social and material components that reveal forms of social life or political rationalities. Although the emergence and characteristics of technological systems grow from the social contexts of their creation, they themselves also trigger new forms of social orders and governance patterns and often a part of the mechanisms of governmentality.¹¹ Technologies and technological infrastructures are not just technical artifacts that have been shaped by the activities of engineers, politicians, managers, regulatory agencies, users, or relevant institutions, but can also shape and enact the visions and imaginaries of their creators and/or users.

Since the early years of the new millennium, a newly established research network of historians of technology in Europe have taken a transnational turn, scrutinizing the universality of systems dynamics. History of technology, and more particularly of large technological systems, became the starting point from which they researched European history and integration. By combining transnational historiography, diplomatic history, history of technological infrastructures, and the history of consumer cultures, this new historiography argues that the invention Europe results from the linking and de-linking European regions, populations, and countries through technological systems. Infrastructural politics and European politics and user practices coproduced European integration in inconspicuous but materially traceable ways. They argue that “hidden integration”, a dynamic techno-political process, shaped Europe not only as a political entity, but also a geography, environment, and culture.¹² The technological history of Europe defines and configures the meaning of modernity in material, cognitive, social, and cultural ways. It is a rich and complex history of visions, framings, and decisions by experts,

⁹ Dalakoglou, “The Road.”

¹⁰ Barry, *Political Machines*; Mitchell, *Rule of Experts*; *Carbon Democracy*; Latour, *Reassembling the Social*; *Science in Action*.

¹¹ Foucault, *The Birth of Biopolitics*; Larkin, “The Politics and Poetics of Infrastructure.”

¹² Kaiser and Schot, *Writing the Rules for Europe*; Oldenziel and Hård, *Consumers Tinkerers, Rebels*; Diogo and van Laak, *Europeans Globalizing*; Högselius et al., *Europe’s Infrastructure Transition*.

flows of knowledge and artifacts that cross borders, diplomatic negotiations and decisions, and tensions by users and consumers. Technologies configure identities and entangle spaces, landscapes, environment, and natural commons.¹³

Global History, Resources and Sustainability History

Recent developments in the history of technology shifted towards approaches and interests that have been developing in global history since the 1950s. As part of post-colonial nation building, nations who had formerly been European colonies began to write their “own” histories, challenging assumptions grounded in Western supremacy. This was intertwined with “history from below” approaches that sought to understand the histories of socially marginalized groups from their perspectives. Such approaches inspired the project *A Global History of Technology*, led by Mikael Hård. Through microhistories, Hård’s project investigated the fate of technologies that circulated in various parts of the world, scrutinizing both Western and non-Western interpretations and practices of these technologies.¹⁴ Newer projects continue to deconstruct dominant narratives, unlocking a diversity of new voices in places from around the globe.¹⁵

The concept of globalization commanded global history interests in the 2000s as a tool to interrogate the emergent relationship between economic development in Asia and European modernization.¹⁶ Hughes’ “war front” metaphor for sociotechnical systems development was taken up by scholars studying what Noboru Ishikawa called the “ecological, social, and cultural compression” of the commodity frontiers.¹⁷ These studies highlight the deep social and ecological impacts and inequalities at specific places of extraction, predominantly in the Global South.¹⁸

Both the histories “from below” and those accounts of globalization speak to contemporary approaches in the history of technology. Technologies and technological infrastructures became tools through which to configure the

¹³ Högselius et al., *Europe’s Infrastructure Transition*; Disco and Kranakis, *Cosmopolitan Commons*.

¹⁴ Hård, “Conclusion: Challenging Globalizing Technologies.”

¹⁵ De Hoop et al. “Historicising Entanglements;” Van der Vleuten and De Hoop, “Crisis Narratives from the Dutch Soyacene.”

¹⁶ Adelman, “What is Global History Now?” Drayton and Motadel, “Discussion: The Futures of Global History.”

¹⁷ Ishikawa, “Into a New Epoch,” 593.

¹⁸ Moore, “Sugar and the Expansion of Early Modern World Economy;” Campling, “The Tuna ‘Commodity Frontier;” Joseph, *Commodity Frontiers and Global Capitalist Expansion*.

meanings and the valorization of nature.¹⁹ Materials and capacities only come to be understood as resources once humans (re)define them as valuable. Valorization processes are dependent on the political, economic, social, and cultural context.²⁰ Through technologies of water management such as big dams, large-scale data infrastructures, or technologies of extraction, natural commons acquire new meanings, new values, new importance, and novel ways of exploitation. They are transformed from their roles within nature into resources to build the technological infrastructures that undergird the national or the cosmopolitan.²¹ New environmental modernities have been defined by the extensive exploitation of natural resources. Technologies of exploration, extraction and genetic modification reconfigured biological raw materials and terrestrial assets like sub-soil resources and fossil fuels. Infrastructures of big data have enhancing and empowering function over technologies of extraction and modification that created new values over nature and raw materials. Recent historiographic approaches link environmental history with the history of technology. In this analytical setting, the emerging field of sustainability history has provided a new historiographic approach that emphasizes the entanglements of nature, technology, and society as key to explaining how modern societies have organized their (un)sustainable modes of existence. Sustainability history aims to link the past with present and future challenges.²² It suggests methodological modalities of studying the past that address present problems but also inform future sociotechnical pathways without getting trapped neither in futurism nor in historical anachronism.²³ Sustainability history establishes a conversation between sustainability studies and national, transnational, and global history.

Starting from coupled systems of human activities and natural processes, it has been expanded to the global history of sustainability to an interconnected, entangled and telecoupled world.²⁴ Transnational and global historical accounts of interconnected societies contribute to sustainability studies a deep understanding

¹⁹ Homburg et al., “The Rise of a Knowledge Society;” Homburg, “Chemistry and Industry.”

²⁰ Bridge, “Material World;” Hecht, *Being Nuclear*; Veraart et al., “Creating, Capturing, and Circulating Commodities.”

²¹ Disco and Kranakis, *Cosmopolitan Commons*.

²² Costanza et al. “Sustainability or Collapse,” 522–27; Trischler, “The Anthropocene,” 309–35; Chakrabarty, “Anthropocene Time;” Van der Vleuten, “Technology and Societal Challenges and Global Sustainability History,” 34–52; Van der Vleuten, “History and Technology in an Age of ‘Grand Challenges’: Raising Questions.”

²³ Caradonna, *Sustainability*; “The Historiography of Sustainability;” *Routledge Handbook of the History of Sustainability*.

²⁴ Liu et al., “Framing Sustainability in a Telecoupled World.”

of historical processes of the global telecouplings of humans and environments, of transnational and global flows of resources and knowledge, and of the effects and impact of couplings in local and global settings.²⁵ Global reconstructions by sustainability historians of entangled societal and economic systems overcome the narrow scope of local histories and expand our understanding of socioecological changes. It goes beyond a history of the ideas of sustainability and a history of the local effects of socioeconomic activities.²⁶ Integrating historical accounts into sustainability studies, “sustainability history” links local environmental histories with histories of transnational infrastructures and global resources supply chains, political economy of natural resources with political and economic transformations, and colonial and post-colonial social orders.²⁷ The actions of entanglers link various regions and communities, resulting in sustainability “trade-offs”, i.e., the economic, social, and environmental sustainability gains and losses within and across regional, national, and transnational boundaries. Focusing on the entanglers and entanglements provides insight into how gains, losses, costs, and revenues were historically distributed across time and space.²⁸

Deep Transitions

Transitions studies insists on the importance of the history of sociotechnical entanglements in the (un)making of industrial modernities. Transitions studies seeks to analyze and steer societal developments onto sustainable pathways. Instead of studying the entanglement of sociopolitical and socioeconomic systems within a single large sociotechnical system (i.e., the energy system, mobility system, healthcare system, etc.), Schot and Kanger stress the importance of studying the deep integration and interdependence of interconnected technological systems and infrastructures. Sociotechnical systems are an expression of rules that determine the development of a given system and ultimately also the evolutionary transformation of society. The Deep Transition approach studies the development and dynamics of

²⁵ Iriye, *Global and Transnational History*; Saunier, *Transnational History*.

²⁶ Du Pisani, “Sustainable Development—Historical Roots of the Concept;” Caradonna, *Sustainability*; “The Historiography of Sustainability;” Lintsen et al., *Well-Being, Sustainability and Social Development*; Veraart et al., “Connected by Oil.”

²⁷ Hecht, *Being Nuclear*; Högselius et al., *The Making of Europe’s Critical Infrastructure*; Högselius et al., “Europe’s Infrastructure Transition;” Heymann et al., “Challenging Europe;” Vikström et al., “Swedish Steel and Global Resource Colonialism;” Vikström, *The Specter of Scarcity*; Åberg and Fjæstad, “Chasing Uranium;” Veraart et al., “Connected by Oil.”

²⁸ Lintsen et al., *Well-Being, Sustainability and Social Development*; Veraart, “Catalysing Socio-Ecological Change,” 370–97.

so-called meta-rules—rules that are shared across different sociotechnical systems. To make society sustainable and inclusive, new meta-rules should be developed in multiple systems. The coupling of rules of different systems is a key element in the formation of meta-rules.²⁹ Others stress the constructed rather than the emergent character of these couplings in sociotechnical entanglements. They attend to the importance and agency of entanglers in making interactions, relations, and interfaces that closely link different technological systems.³⁰ Historians have identified as entanglers institutions, key individuals, technical societies, NGOs, governmental and trans-governmental institutions responsible for the funding, regulation and control of systems.³¹ Entanglers can function as sociotechnical vanguards, individuals, or small collectives who frame specific visions for the future and take actions for the realization and diffusion of those visions. The vanguards have a visionary role and present themselves as having a privileged understanding of new technologies, capable of promoting the socioeconomic potential of technological transformations. Sociotechnical vanguards are key actors who transform, stabilize and institutionalize visions about technological performance, efficiency, and progress into social imaginaries. By using the tools of narrative, comparison, and enticement, they link the past with the present and future, and they catalyze sociotechnical transformations and entanglements.³²

The Special Issue: Structure and Content

This special issue links the history of technology with environmental history and the history of agrifood systems, as it offers insight into many entanglements of technological infrastructures, resources, social orders, and varieties of modernity in Europe and beyond. The articles unravel the agency of entanglers as a key element in cross-system couplings and meta-rule creation in sociotechnical systems as well as in configuring sustainability trade-offs that shaped environmental modernities.

The issue starts with two articles that reconstruct the entangled histories of technological developments in agriculture and agrifood industries. These technological developments defined the modes of production and configured the impact of the agriculture/agrifood entanglement on system formation, system phase-out, and environmental externalities. The first article, by John Martin,

²⁹ Schot, “Confronting the Second Deep Transition through the Historical Imagination,” 445–56; Kanger and Schot, “Deep Transitions,” 7–21; Schot and Kanger, “Deep Transitions: Emergence, Acceleration, Stabilization and Directionality.”

³⁰ Van der Vleuten, “Radical Change and Deep Transitions.”

³¹ Arapostathis and Laborie, “Governing Technosciences in the Age of Grand Challenges.”

³² Hilgartner, “Capturing the Imaginary,” 33–55.

highlights agricultural innovators associated with three different agricultural revolutions that have taken place in Britain since the seventeenth century. In this article, special attention is given to the twentieth-century state-controlled modernization of agriculture during economic crisis, wartime, and post-war developments. The second article, by Sotiris Alexakis and Stathis Arapostathis, studies transitions in the agricultural modernization in Greece as a history wherein technological transformations entangle with “colonized ecosystems.”³³ It highlights the role of entanglers in configuring couplings of the agricultural development with other sociotechnical systems, such as mining and water management. It argues that these connections created strong path dependencies that hinder efforts for a more sustainable agricultural practice.

The next two articles offer a transnational perspective. The third article of this special issue, by Klara Strecker and Frank Veraart, invokes a telecoupling framework to analyze the historical development of the international trade of roses between Kenya and the Netherlands. It shows how the Netherlands developed into the major international hub for this luxury commodity. With a focus on both human and non-human actors, including policymakers, traders, consumers, and the rose itself, this article explains the dynamic entanglements and disentanglements of this sociotechnical system. It argues that these transformations shaped and shifted rose production from Dutch greenhouses to efficacious sociotechnological systems in Kenya and other East African countries. In article four, Claiton da Silva and Claudio de Majo present various Western and non-Western interpretations of modernization that emerge through the deforestation practices taking place in the Amazon rainforest of Brazil. A paradoxical contrast takes shape whereby contemporary deforestation practices are couched in narratives, histories and imaginaries of modernization but greatly resemble pre-industrial deforestation practices which used large and uncontrolled fires. This article gives voice to diverse local and international interpretations of the fires and their economic, environmental, and political reach.

The last set of articles in this special issue present entangled histories of organizational, institutional, and technological innovations in resource exploration and governance. These highlight how entanglers’ agency shape sociotechnical systems. The fifth article, by Robrecht Declercq, explores the role of experts in the economic geology and mining industries. Focusing on copper industries, he presents a historical reconstruction that connects multiple geographies around the world. He shows the role of these technologies, knowledge production and expertise in entangling regions of resources with industrial interests, and resource policies. The last article, by Efi Nakopoulou and Stathis Arapostathis, enhances

³³ Lintsen et al., *Well-being, Sustainability and Social Development*.

the analysis of the techno-politics of entanglers. They highlight the connections between European renewable energy research policies and resource politics. The article reveals the new and developing relations of Europe with China and countries in the Global South. Nakopoulou and Arapostathis highlight a new geopolitics that entangles the European transition to more sustainable energy production and gives way to new global dependencies.

The contributions offer a kaleidoscopic overview that foregrounds many manifestations and variations of (dis)entanglements and (dis)entanglers, and of human and non-human actors. The articles additionally highlight the sometimes winding paths that the entangling and disentangling processes cause as sociotechnical systems develop, and how this shapes economic, social, and environmental developments in the affected regions.

Biographies

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