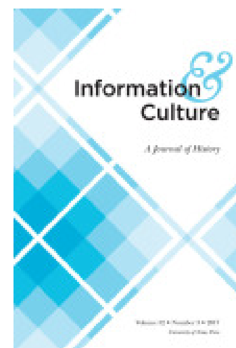
Computing and the Environment: Introducing a Special Issue of *Information & Culture*



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In much of the literature on the information society, its defining characteristic is assumed to be its immateriality. That is to say, as our interactions and activities become less dependent on the movement of atoms and more focused on the manipulation of bits, they seem less limited by the constraints of physical reality. But when we look closely at the material underpinnings of the information economy—from the minerals that make up digital devices to the massive amounts of energy and water required to power data centers—it becomes clear that information technologies are firmly grounded in the physical environment. In fact, information technologies continuously shape not only the physical environment but also representations of the relationship between natural and built worlds.

In his 1995 best seller *Being Digital*, the high-tech visionary and MIT professor Nicholas Negroponte predicted the triumph of the informational over the material. The driving force behind the impending digital revolution, according to Negroponte, was the superiority of bits over atoms. In earlier eras the dissemination of information required the movement of physical material (atoms), and traffic on the digital information superhighway was entirely made up of weightless, immaterial bits, all of them traveling at the speed of light in a frictionless environment. Whereas the movement of atoms was expensive, the distribution of bits was effectively cost-free: as a result, Negroponte argued, the "rapid exponential shift from atoms to bits" in modern economic, social, and political life was both "inevitable and unstoppable."[1]

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Negroponte was only one of many pundits in this period suggesting that the defining characteristic of the digital economy was its essential "weightlessness."[2] From John Perry Barlow to Alan Greenspan to the editors of *Wired Magazine*, claims about the "dematerialization" of information dominated the discussion about digital technology.[3] Whether one was arguing for the deregulation of telecommunications networks or the achievement of a posthumanist utopia, the fundamental assumption was that, with the development of digital technologies, information had been "rendered free from the material constraints that govern[ed] the material world."[4] Indeed, such claims date back at least from the mid-1970s, when the sociologist Daniel Bell introduced the notion of the postindustrial economy into popular discourse. The postindustrial economy would be characterized, according to Bell, by a shift from manufacturing to service, from production to consumption, and from the material to the informational.[5] In his 1977 Pulitzer Prize–nominated book, James Martin described this brave new world as the "Wired Society," making explicit the connection between the postindustrial economy and recent developments in digital technology.[6] In anticipation of Negroponte's "atoms-to-bits" argument, Martin predicted that the inexpensive and instantaneous connectivity made possible by information technology (a phenomenon that Frances Cairncross would later call the "death of distance") would allow for a radical restructuring of both social and geographical relationships.[7] In fact, for Martin, the ultimate result of this newfound freedom would be a postindustrial return to preindustrial patterns of rural settlement. Freed from the need to engage in physically embodied forms of information exchange, humans would choose country over city and would return to a simpler, more local, and more pastoral existence.

Many scholars have challenged the digital utopian vision.[8] The postindustrial society has not materialized (or dematerialized) in the ways predicted; efforts to ship bit-producing labor overseas have alternately reduced opportunities in the nation where the digital revolution was purportedly born and demonstrated the difficulties and limitations of disaggregating computer-mediated work across globally dispersed social contexts. Barlow ultimately sold his ranch and moved to the city. While the rise of computer networks has enabled new patterns of work, it has not stopped the growth of megacities, nor has it radically reshaped the relationships between built and natural environments.

Or has it? Today people navigate cities, roadways, and wilderness using global positioning systems. Our understanding of the most pressing environmental problem of our time—global climate change—would be extremely limited without the assistance of massive databases and complex programs for simulation.[9] While much has been written about the role of computing in reshaping work practices, as well as limitations to such changes, scholars have yet to systematically evaluate the role of information technology in environmental change. The essays in this issue examine these important themes, showing that information technology has both impacted physical environments in ways little acknowledged by digital utopians and contributed to new representations of and interventions into the relationship between built and natural environments.

As Christophe Lécuyer's article, "From Cleanrooms to Dirty Water: Labor, Semiconductor Firms, and the Struggle over Pollution and Workplace Hazards in Silicon Valley," reminds us, even in the heart of the postindustrial digital economy, workers and labor activists soon discovered that atoms and bits were not so easy to disentangle. Although the semiconductor firms that provided the region with its name had long represented themselves as a "clean" industry, their impact on the environment and human health was not less significant than their impact on the digital economy but simply less visible. As the largely female and immigrant laborers in Silicon Valley fabrication plants began to suffer from acid burns, chemical sensitivity, and higher than normal rates of breast and other cancers, it became increasingly clear that, despite the lack of obvious smokestacks, factory work in the new economy was not so different from factory work in the earlier industrial economy. The staggeringly expensive "cleanrooms" in microchip fabrication plants were meant to protect components, not people. By the early 1980s it had become increasingly clear that the underground tanks used to store the toxic by-products of semiconductor manufacture were leaking into the groundwater, meaning that even those working in the more abstract, information-oriented occupations in Silicon Valley were not immune to the effects of postindustrial industrial manufacturing. By the end of the 1980s the Environmental Protection Agency had identified twenty-nine Superfund sites in Santa Clara County, the single largest concentration of such sites in the nation. The story Lécuyer tells is as much about continuity with industrial modes of production as it is about change to a postindustrial society. The themes that he explores are industrial-era concerns about worker safety, collective bargaining, and environmental degradation. Their surprising familiarity throws into stark relief the self-serving narratives told by high-tech employers about the unprecedented immateriality of the information economy.[10]

Today most of the manufacturing activities that proved so toxic to Santa Clara County have been relocated to other parts of the world, thus rendering their environmental costs and impacts even less visible to their primary consumers and beneficiaries. But all of the material components of our digital devices come from somewhere, and the story about how they get from there to here—in other words, the history of the global supply chain of the digital economy—can be used to connect the history of computing to a larger history of the environment. At the most basic level, the minerals that make up these components must be extracted from the ground, often at great cost to both human health and the environment. Some of these minerals—tin, for example—are dangerous to humans and animals alike and are associated with widespread ecological disasters; others, such as lithium, are concentrated in parts of the world with a long history of colonial and postcolonial exploitation of the environment.[11] In the case of the rare earth elements, essential to both the information technology and alternative fuels industries, the centralization of control in the hands of a small number of nations raises a specter of contentious geopolitical conflict that rivals that of the petrochemical economy.[12]

Even after these minerals are successfully collected and transported, they must be cleaned and decontaminated in processes that require massive amounts of water, electricity, and chemicals and that produce large amounts of toxic by-products that must be stored or otherwise disposed of.[13] Much of this work is concentrated in the massive industrial cities of southern China, which further exacerbates the rate of environmental degradation.[14] And these industrial pollutants are but part of a much larger problem of electronic waste (e-waste) that implicates the entire digital economy in the transnational flow of toxic materials that disproportionately affects the environment and citizens of the developing world.[15] In computer graveyards in places such as Agbogbloshie, Ghana, carcinogens such as lead, mercury, arsenic, cadmium, and chlorinated dioxins are dumped directly into landfills, contaminating both the local soil and the groundwater supply.[16] While such stories are tragic, they are nevertheless familiar. This is the history of industrial capitalism, recapitulated and transformed within the information economy.

As Lécuyer's presentation of this history makes clear, there are good reasons why information technology firms work to conceal their physical presence and material reality under the cloak of ethereal metaphors such as the "cloud."[17] The rhetoric of the cloud implies lightness, immateriality, and impermanence. But when we look closely at the underlying technologies that make the cloud possible—from copper wires to underwater cables to coal-fired electrical generators—it is revealed to be simply a reconfigured network of industrial-era physical infrastructures.[18] At the nodes of this network sit large warehouses full of electronics equipment, all of which require large amounts of energy to run and water to cool.[19] In the past few years media scholars have productively explored the materiality of this information infrastructure, and it is to this literature that Julie Cohn's article, "Data, Power, and Conservation: The Early Turn to Information Technologies to Manage Energy Resources," contributes most directly.[20]

In her article, Cohn focuses on the role of information technology in mediating between a potent engine and symbol of modernity—electrification—and the natural environment upon which it relies, including coal deposits and rivers. Throughout the twentieth century, electrification helped to define the boundary between built and natural environments through the development of mining infrastructure, the construction of hydroelectric dams, and the development of electrified environments that aim to protect humans from the caprice of nature. Cohn demonstrates the centrality of information technology to this process as it has unfolded in the United States. Beginning in the early twentieth century, the US electricity industry used information technology to help deliver electricity with increasing physical efficiency, thereby consuming fewer natural resources per watt of power delivered. However, the specific goals of conservation shifted throughout the twentieth century, from Progressive Era concerns with natural resource management, to increasing defensive industrial productivity for World War II, to the postwar faith in ever-cheaper electrification as the source of American prosperity and progress. As Cohn notes, the recent notion of conservation—a focus on a net decrease and even elimination of natural resource consumption—marks a significant departure from all earlier understandings. For most of the twentieth century, information technology made electrification systems more efficient but did not decrease the net consumption of resources; on the contrary, one means of increasing efficiency was to increase consumption, thereby gaining economies of scale. Contemporary efforts to make the electrical grid "smart" continue many decades of developing information technology that can improve efficiency but are driven by a relatively new understanding of the ultimate goals of such improvements: to reduce and even eliminate the use of nonrenewable natural resources such as coal. There has always been a close connection between electrical and information infrastructures, but this has become even closer in recent decades.[21]

It is particularly appropriate that Cohn focuses on the electrical grid as a form of information infrastructure, because as the historian Thomas Hughes notes in response to Nicholas Negroponte, the absolutely essential element of digital technology is not the bit but the electron.[22] You can have electronic digital computers without binary digits, but you cannot have them without electricity. And the energy requirements of the information economy are astounding: according to a recent Greenpeace report, if the cloud were a country, it would be the sixth largest energy consumer on the planet.[23] The collective global demand for power for digital data centers accounts for the output of roughly thirty nuclear power plants, with server farms in the United States accounting for as much as one-third of this total load. In 2011 Google data centers alone used more than 2.3 billion kilowatt-hours of electricity, which represented about 2 percent of the annual electricity consumption of the entire United States. For all the talk about cyberspace as an ethereal realm of information sitting outside of physical and political geography, in reality, data centers and server farms need to be located near inexpensive sources of power and at the nodes of energy distribution grids. When we look at the vast web of wires, cables, towers, generators, and other physical equipment that underlies the apparently virtual realm of cyberspace, we see that these are exactly the same forms of infrastructure required by more traditional forms of manufacturing. Seen from this perspective, the digital present does not seem quite so discontinuous with our industrial past.[24]

Historians who specialize in technology and environment have identified at least three important ways in which these two seemingly very distinct topics can be understood to interact. To begin with, they are interested in the ways in which humans use technology to shape or influence their environment. Second, they emphasize the active role that nature plays in shaping human behavior and activity. Finally, they are concerned with the ways in which technologies mediate or alter the ways in which humans perceive and understand their environment. It is in this last category that we can situate Lisa Avron's article, "'Governmentalities' of Conservation Science at the Advent of Drones: Situating an Emerging Technology."

Avron examines the use of remotely piloted aircraft, also known as Unmanned Aircraft Systems (UAS) or drones, for wildlife management and conservation. She demonstrates both continuities and changes between conservation drones and earlier information systems used to represent natural landscapes and populations in wildlife management. Today many scientists are excited about the unprecedented levels of precision offered by digital images collected by remotely piloted aircraft, as well as the reduced costs and hazards to humans, who no longer must risk life and limb hanging out of aircraft to take photos. Yet as Avron shows, research conducted with conservation drones continues and combines multiple rationalities governing wildlife management. While biopolitical rationalities are focused on restoring the natural environment to its "native" or "pure" state by eliminating "invasive" and "impure" species, neoliberal rationalities are focused on managing the natural environment in ways that enable economic growth and the development of built environments. Using ethnographic research on a UAS research program in Florida, Avron shows that conceptions of "invasive" or "natural" species are shaped by a history of human development, as well as by contemporary interests in continuing that development for economic benefit. As she argues, conservation drones are information systems that "aid in transforming a native species (the Carolina willow) into an 'invasive nuisance'" by helping to quantify the costs that the water-thirsty willow imposes on the equally water-thirsty development of coastal cities in Florida.

Over the course of the past decade, the incorporation of insights drawn from environmental history has helped to reinvigorate the discipline of the history of technology.[25] In thinking critically about the relationship between the natural and the built environments, historians of technology have been able to expand the scope of their discipline to include a broader range of actors and a more global perspective and sensibility. Our goal in putting together this special issue on computing and the environment has been to provoke a similarly productive exchange within the community of scholars who study information technology.

Notes

1. Nicholas Negroponte, *Being Digital* (1995; New York: Knopf, 2015).

2. Diane Coyle, *The Weightless World: Strategies for Managing the Digital Economy* (Cambridge, MA: MIT Press, 1999).

3. Frans Berkhout and Julia Hertin, "De-materialising and Re-materialising: Digital Technologies and the Environment," *Futures* 36, no. 8 (2004): 903–20; John Perry Barlow, "A Declaration of the Independence of Cyberspace," 1996, https://www.eff.org/cyberspace-independence; Kevin Kelly, *New Rules for the New Economy: 10 Radical Strategies for a Connected World* (New York: Penguin, 1999).

4. Jean-François Blanchette, "A Material History of Bits," *Journal of the American Society for Information Science and Technology* 62, no. 6 (2011): 1042–57.

5. Daniel Bell, *The Coming of Post-industrial Society* (New York: Basic Books, 2008).

6. James Martin, *The Wired Society* (New York: Prentice-Hall, 1978).

7. Frances Cairncross, *The Death of Distance: How the Communications Revolution Is Changing Our Lives* (Boston: Harvard Business Review Press, 2001).

8. For just a few examples, see A. Aneesh, *Virtual Migration: The Programming of Globalization* (Durham, NC: Duke University Press, 2006); Fred Turner, *From Counterculture to Cyberculture* (Chicago: University of Chicago Press, 2006); Langdon Winner, "Mythinformation" in *The Whale and The Reactor* (Chicago: University of Chicago Press, 1986), 98–120; "Cyberlibertarian Myths and the Prospects for Community," *ACM SIGCAS Computers and Society* 27, no. 3 (1997): 14–19.

9. Paul Edwards, *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming* (Cambridge, MA: MIT Press, 2010).

10. In his book *Toxic Town*, Peter Little tells a remarkably similar story about the East Coast analogue to Silicon Valley, the iconic IBM company town of Endicott, New York. Endicott was also the site of massive groundwater contamination from the by-products of electronics manufacturing. But because Endicott failed to thrive in the postmanufacturing information economy, the harsh consequences of deindustrialization are even more apparent there than they are in Silicon Valley. Peter Little, *Toxic Town: IBM, Pollution, and Industrial Risks* (New York: NYU Press, 2014).

11. Seth Fletcher, *Bottled Lightning: Superbatteries, Electric Cars, and the New Lithium Economy* (New York: Hill & Wang, 2011); Kyung Taek Rim, Kwon Ho Koo, and Jung Sun Park, "Toxicological Evaluations of Rare Earths and Their Health Impacts to Workers: A Literature Review," *Safety and Health at Work* 4, no. 1 (March 2013): 12–26.

12. Keith Veronese, *Rare: The High-Stakes Race to Satisfy Our Need for the Scarcest Metals on Earth* (New York: Prometheus Books, 2015); Richard Stone, "As China's Rare Earth R&D Becomes Ever More Rarefied, Others Tremble," *Science* 325, no. 5,946 (2009): 1336–37.

13. Lenny Siegel and John Markoff, *The High Cost of High Tech: The Dark Side of the Chip* (New York: HarperCollins Publishers, 1985); Hua-Mei Chiu, "The Dark Side of Silicon Island: High-Tech Pollution and the Environmental Movement in Taiwan," *Capitalism Nature Socialism* 22, no. 1 (March 2011): 40–57.

14. Burak Güneralp and Karen C. Seto, "Environmental Impacts of Urban Growth from an Integrated Dynamic Perspective: A Case Study of Shenzhen, South China," in "Local Evidence on Vulnerabilities and Adaptations to Global Environmental Change," ed. Lilibeth Acosta-Michlik, special issue, *Global Environmental Change* 18, no. 4 (October 2008): 720–35.

15. Jennifer Gabrys, *Digital Rubbish: A Natural History of Electronics* (Ann Arbor: University of Michigan Press, 2013).

16. Greenpeace, *Poisoning the Poor: Electronic Waste in Ghana* (Washington, DC: Greenpeace, August 2008).

17. John Durham Peters, *The Marvelous Clouds: Toward a Philosophy of Elemental Media* (Chicago: University of Chicago Press, 2015); Tung-Hui Hu, *A Prehistory of the Cloud* (Cambridge, MA: MIT Press, 2015).

18. Nicole Starosielski, *The Undersea Network* (Durham, NC: Duke University Press, 2015); Jeff Hecht, *City of Light: The Story of Fiber Optics* (Oxford: Oxford University Press, 2004); Nathan Ensmenger, "Computation, Materiality, and the Global Environment," *IEEE Annals of the History of Computing* 35, no. 3 (2013): 78–80.

19. Mél Hogan, "Data Flows and Water Woes: The Utah Data Center," *Big Data & Society* 2, no. 2 (December 27, 2015): 1–12.

20. Erkki Huhtamo and Jussi Parrika, *Media Archaeology: Approaches, Applications, and Implications* (Berkeley: University of California Press, 2011); Tarleton Gillespie, Pablo Boczkowski, and Kirsten Foot, *Media Technologies: Essays on Communication, Materiality, and Society* (Cambridge, MA: MIT Press, 2014); Nicole Starosielski and Janet Walker, *Sustainable Media: Critical Approaches to Media and Environment* (New York: Routledge, 2016).

21. Rebecca Slayton, "Efficient, Secure Green: Digital Utopianism and the Challenge of Making the Electrical Grid 'Smart,'" *Information & Culture* 48, no. 4 (2013): 448–78.

22. Thomas P. Hughes, *Human-Built World: How to Think about Technology and Culture* (Chicago: University of Chicago Press, 2004).

23. Gary Cook, *Clicking Clean: How Companies Are Creating the Green Internet* (Washington, DC: Greenpeace, 2013).

24. Nathan Ensmenger, "Towards an Environmental History of Computing," *Technology and Culture*, forthcoming.

25. Jeffrey K. Stine and Joel A. Tarr, "At the Intersection of Histories: Technology and the Environment," *Technology and Culture* 39, no. 4 (October 1998): 601; Edmund Russell et al., "The Nature of Power: Synthesizing the History of Technology and Environmental History," *Technology and Culture* 52, no. 2 (2011): 246–59; Dolly Jørgensen, Finn Arne Jørgensen, and Sara B. Pritchard, *New Natures: Joining Environmental History with Science and Technology Studies* (Pittsburgh, PA: University of Pittsburgh Press, 2013); Sara B. Pritchard, *Confluence* (Cambridge, MA: Harvard University Press, 2011).