

## CHAPTER 3

# “Where the Internet Lives”

## Data Centers as Cloud Infrastructure

JENNIFER HOLT AND PATRICK VONDERAU

Emblazoned with the headline “Transparency,” Google released dozens of interior and exterior glossy images of their data centers on the company’s website in 2012. Inviting the public to “come inside” and “see where the Internet lives,” Google proudly announced they would reveal “what we’re made of—inside and out” by offering virtual tours through photo galleries of the technology, the people, and the places making up their data centers.<sup>1</sup> Google’s tours showed the world a glimpse of these structures with a series of photographs showcasing “the physical Internet,” as the site characterized it. The pictures consisted mainly of slick, artful images of buildings, wires, pipes, servers, and dedicated workers who populate the centers.

Apple has also put the infrastructure behind its cloud services on display for the digital audience by featuring a host of infographics, statistics, and polished inside views of the company’s “environmentally responsible” data center facilities on its website.<sup>2</sup> Facebook, in turn, features extensive photo and news coverage of its global physical infrastructure on dedicated Facebook pages, while Microsoft presents guided video tours of their server farms for free download on its corporate website.<sup>3</sup> Even smaller data centers like those owned by European Internet service provider Bahnhof AB, located in Sweden, are increasingly on digital exhibit, with their corporate parents offering various images of server racks, cooling and power technology, or even their meeting rooms, all for wide dissemination and republishing.<sup>4</sup> Operating out of a Cold War

civil-defense bunker hidden thirty meters under the earth, Bahnhof's "Pionen White Mountains" center (its original wartime codename) offers particularly dramatic sights, complete with German submarine diesel engines for backup, and glowing, windowless rock walls protecting blinking servers stacked underground. Alongside such memorable online representations of server facilities, there is also a recent array of coffee-table books, documentaries, news reports, and other offline forms of photographic evidence that have put data centers on display.<sup>5</sup>

But what are all these images about? What drives this excess of vision that asks us to partake in creating visibility for something that remains essentially invisible? Why do we engage in sharing views of emptied, technified spaces? At first glance, on a surface level, the visible evidence abundantly provided by Google, Apple, or Bahnhof might simply appear as a means of creating a positive public image of the data center business. Given the centralization of data in "the cloud," such pictures persuade users to experience the move of their data to corporate "warehouses" as being safe and secure, by depicting a stable and nonthreatening cloud storage environment.<sup>6</sup> Indeed, the notion of the cloud is a marketing concept that renders the physical, infrastructural realities of remote data storage into a palatable abstraction for those who are using it, consciously or not. In fact, a recent survey of more than one thousand Americans revealed that 95 percent of those who think they are not using the cloud, actually are—whether in the act of shopping, banking, or gaming online, using social networks, streaming media, or storing music/photos/videos online.<sup>7</sup>

However, explaining data-center visibility by pointing to the discourses it shapes, to the metaphorical character of "the cloud," or to the ways the cloud is rendered visible by looking "behind the scenes" of another scale economy can merely be first steps. Looking deeper will lead us to acknowledge that much of what we see in these images is also indicative of the competitive dynamics between Google, Apple, and Facebook. Picturing infrastructure means staking corporate territory, given that this infrastructure as well as the software or services it makes accessible are often proprietary and subject to disputes over interoperability issues.<sup>8</sup>

Following this line of thought, we might still take a further step and start observing the rather intense "technological dramas"<sup>9</sup> playing out in the imagery of digital infrastructure. Google and Bahnhof offer especially pertinent examples of what Langdon Winner called the "politics of artifacts": the way working systems choreograph the relationship between technologies and the people using them—and in between themselves.<sup>10</sup> And indeed, how can we overlook the polity-building processes implied in Google's infrastructure design—its



**Figure 3.1.** Douglas County, Georgia, data center. Shown here are colorful pipes distributing water for cooling the facility, and Google's G-bike, the "vehicle of choice" for transportation in and around the data centers.



**Figure 3.2.** Bahnhof data center, Stockholm, Sweden.

lively colored pipes, well-organized lines of glowing server racks in shades of blue and green, and brightly illuminated architectural spaces—as compared with Bahnhof's underground Cold War bunker setting and historical engine for backup power?

Google's data centers literally span the globe, and their images imply a seamless, universal connection, a benevolent global reach, and even a no-impact environmental presence with a corporate-designed bicycle featured in one shot

as the “transportation of choice” around the data center. Bahnhof’s website, on the other hand, advertises heavily protected security in three separate data centers (one of which is a nuclear bunker) with “TOP SECRET” stamps across the homepage. Further, there are proud proclamations and lengthy explanations about the company’s valuing the right to freedom of speech and being the host for Wikileaks, along with a link to the Ebay auction for the Wikileaks data server.<sup>11</sup> Indeed, the images of Bahnhof’s data centers speak to us about the ways that Europe’s “oldest and strongest legislations for freedom of speech and freedom of information” have been built into the very facilities servicing access to data.<sup>12</sup> In short, such images tell us about affordances and constraints turned into pipes and cables, about in-built political values and the ways the engineering of artifacts come close to engineering via law, rhetoric, and commerce. And the images also testify to the constant struggles over standards and policies intrinsic to the network economy.<sup>13</sup>

Or so we may think. For what is most striking about these images is, of course, precisely that which we do not see. Google’s and Bahnhof’s images gesture toward the notion of transparency, all while working to conceal or obscure less picturesque dimensions of cloud infrastructure. We learn nothing, in Google’s case, about its mechanical, electronic, or technical infrastructure design, energy use, or network infrastructure; in fact, Google is notoriously secretive about the technical details of its servers and networking capabilities in the interest of security as well as competitive strategy.<sup>14</sup> Nor do Bahnhof’s photos tell us anything about how much this “free speech” Internet service provider’s business actually is built on unauthorized traffic—in Sweden, piracy has been key to the media and IT industries’ development, selling conduits and connectivity.<sup>15</sup> Hence, a third and final step is required: we need to acknowledge that many of the operations, standards, and devices we are trying to describe when analyzing digital infrastructure will remain hidden, locked away, or, in engineering terms, “blackboxed.” As Bruno Latour has pointed out, the mediating role of techniques is notoriously difficult to measure, at least as long as the machines run smoothly; the more technology succeeds, the more opaque it becomes.<sup>16</sup> Although Google and Bahnhof provide branded services and platforms, and thus are readily apparent to their users, their infrastructures remain blackboxed. Data centers are information infrastructures hiding in plain sight.<sup>17</sup>

This chapter discusses data centers as the material dimension of “the cloud” and as a critical element of digital media infrastructures. To render cloud computing truly visible, we need to understand the material support systems for data storage and data transmission, or the “stuff you can kick,” as described by Lisa Parks—the bricks and mortar, physical networks of digital media distribution.<sup>18</sup>

Additionally, we also need to "see" the standards and protocols, affordances and constraints built into these networks. While distribution infrastructures always have been designed to be transparent,<sup>19</sup> transparency as immaterialized in "the cloud" has turned into an all-purpose political metaphor for the fact that we are storing our data (or our company's data) on someone else's servers in an undisclosed location that we will never be able to see. In following media archaeology's "non-representational take on politics," its interest in the "non-sense of something that cannot be exchanged for meaning,"<sup>20</sup> we are turning to what Susan Leigh Star has referred to as the "boring backstage elements"<sup>21</sup> of online delivery, or, in the case of data centers, where "the cloud" touches the ground. Connecting the metaphor and imagery of the cloud to data centers and Internet topology, we aim to discern structures of power through technological and industrial analysis.<sup>22</sup>

## The Technopolitics of Hypervisibility

Data centers are the heart of "the cloud" and much of its physical infrastructure. They *are* the physical presence of this imaginary space, and yet they strive to remain invisible in many ways. They maintain a high degree of secrecy, allowing very few visitors from the outside in, and keeping their locations, operating procedures, or devices largely out of the press as a matter of security—and competition in the market. In fact, the refusal to discuss where they are located, how many there are, and other details about how and how much data is processed in these centers has led some in the industry to liken the culture of confidentiality surrounding server farms to the ethos of *Fight Club* ("The first rule of data centers is don't talk about the data centers").<sup>23</sup>

One notable exception to this protective veil of secrecy occurred with Google's 2012 public relations push to promote their data centers as visible, accessible, and environmentally friendly. The images of technology on the site devoted to "revealing" their data centers offer colorful shots of computers, wires, routers, switches, pipes, and hard drives that arguably render this infrastructure much less visible when decontextualized. Indeed, it almost appears as abstract art; there is no trace of any relationship between these technological components and the processing, storing, cooling, or distributing trillions of gigabytes (now known as zettabytes) of data—or the attendant environmental implications (see figure 3.3).

The structures where this all takes place have also been hyperstylized to showcase the natural environment and seemingly make the visual argument that the landscape is even *more* beautiful *because of* the giant data center in the picture. There are portraits of lush wildflowers, mist rising above the Columbia





**Figure 3.4.** The Dalles, Oregon.



**Figure 3.5.** Council Bluffs, Iowa data center with deer in the foreground.







(silicon, copper, plastics, and the like) as much as by a political form (liberalism) that attempts to organize users and territories through domains that seem far removed from politics. Media infrastructures are indicative of such a mode of governing that disavows itself while at the same time constantly overexposing its material designs in order to represent, for all those who want to see, how modern our possible futures and futures present have become. It is these "politics of 'as if'"<sup>40</sup> that are so overtly discernible in Google's or Bahnhof's intensely stylized images of denuded technologies. In this sense, data centers can be described as persuasive designs: as artifacts that aim to steer user behavior and attitudes in an intended direction while constraining others.<sup>41</sup> It is for these reasons that we also direct our analysis toward the very practices of conceptualizing digital media infrastructure, both in terms of imagery and topology, rather than simply looking at its social, ecological, or economic effects.

### Cloud Imaginaries and Energy Requirements

The data that is processed and stored in "the cloud" is vital to the constant flow of news, information, software, and entertainment that populates the digital media landscape. The data *about* this data has become similarly important to defining "the cloud" for the popular imaginary; as the amount of bits being utilized defies comprehension, comparisons to football fields, metaphors about cities, even representations in the form of data scaling Mt. Everest have been drawn in order to make this data and its environment "visible" or understandable in some way (see figure 3.7).

The amount of data that is estimated to be currently stored in the cloud is more than one billion gigabytes; it is also, as one industry report has characterized it, the same as 67 million iPhones worth of data.<sup>42</sup> These and other comparisons give contours (albeit often absurd ones) to the remote storage

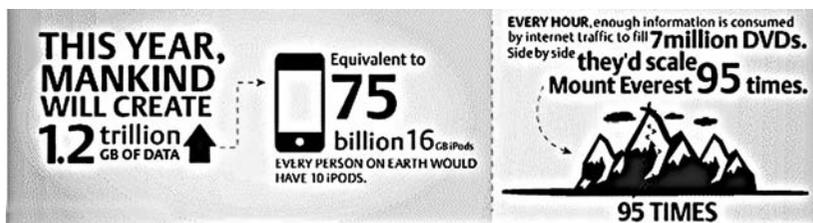


Figure 3.7. Image from *State of the Data Center, 2011* infographic. Emerson Network Power, <http://www.emersonnetworkpower.com/en/US/About/NewsRoom/Pages/2011DataCenterState.aspx>.

capabilities and infrastructure known as “the cloud,” which, other than the aforementioned representations of data centers and their decontextualized technologies, remains largely immaterial, dimensionless, and almost impossible to even imagine. Such metaphors also serve to “contain the messy reality” of infrastructure, as described by Star and Lampland.<sup>43</sup> Yet despite these creative numerical valuations, Fuller and Goffey have articulately observed in their analysis of infrastructure’s abstractions that “empirical states of fact obtrude but tangentially on the marketing of hyperbole.”<sup>44</sup> Indeed, the more sober “facts” about the infrastructure of the cloud rarely collide with the PR-fueled sensational dramatizations and depictions most commonly circulated. Despite the corporate promotion of “cloud computing” and “cloud storage” as abstract, celestial panaceas for managing digital content, there are still considerable concrete, earthbound challenges for this cloud infrastructure as the demand for access to offsite data continues to explode.

The ways that cloud infrastructure is regulated present one significant challenge. Currently, it is almost a legal impossibility to discern, for example, the jurisdiction and often the sovereignty of the data that is processed, stored, circulated, and transmitted by the millions of data centers all over the globe.<sup>45</sup> It is also extremely difficult to regulate various players in the distribution chain of data from storage to consumer, including Content Delivery Networks (CDNs) and Internet Service Providers (ISPs) that have “peering” agreements. Various interconnection points along the distribution chain are notoriously opaque in their reporting of costs, speed, and connection quality. Regulators also lack the metrics and tools necessary to effectively monitor any anti-competitive or anti-consumer behavior in this industry because of the lack of transparency on the part of the companies involved.<sup>46</sup> This arena would benefit from some genuine visibility, as it is often marginalized in the landscapes of infrastructural concerns.

The amount of energy required to power and cool data centers remains chief among those concerns. These facilities are one of the fastest growing consumers of energy, and they are expanding rapidly. In fact, Google’s investment alone during 2013 on expanding their centers represents the largest investment in data center infrastructure in the history of the Internet.<sup>47</sup> The resulting energy needs of “the cloud” are indeed astronomical: a single data center can require more power than a medium-size town.<sup>48</sup> According to a recent Greenpeace report examining the energy consumption of data centers and the various components of “cloud power,” if the cloud were a country, it would have the fifth largest electricity demand in the world.<sup>49</sup> It has also been estimated that data centers can waste 90 percent of the power that they pull off the grid, and their carbon footprint will likely surpass that of air travel by 2020.<sup>50</sup> The definition

of “wasting” power has been debated in this context—a recent *New York Times* investigation found that, on average, data centers were using only 6 percent to 12 percent of the electricity powering their servers to perform computations. The rest was essentially used to keep servers idling and ready in case of a surge in activity that could slow or crash their operations.<sup>51</sup> However, the reserve power is an insurance policy against disaster (in other words, an outage that cuts off all access to the cloud services that largely support the global economy). The value in having this insurance built into the design of data centers is apparently worth the cost to those who own them, revealing much about the logics of cloud infrastructure, which—much like nuclear power plants—are rooted in excess, redundancy, and contingency, governed by the looming specter of worst-case scenarios.

Thanks to these requirements, the proximity to affordable electricity and energy sources are a paramount consideration when determining where to build and locate data centers. The average temperature and climate are also increasingly being factored in to such decisions as more companies try to take advantage of “free cooling” or the use of outside air instead of energy-intensive air conditioning to cool the massive racks of computer servers and prevent them from overheating (which essentially causes the cloud to “disappear”). Lower temperatures outside present significant cost savings inside, as at least half of a data center’s energy footprint has historically come from the energy required to keep the servers cool.<sup>52</sup> As a result, there is a growing interdependency between the developing topography of cloud infrastructure and energy politics. Google is at the forefront of this complex relationship, as the company uses roughly one million servers in what has been estimated to be dozens of data centers.<sup>53</sup> Their data center in The Dalles, Oregon, sits on the Columbia River and uses renewable hydropower to run the center. Google is also becoming a growing power “broker”—investing more than \$1 billion in clean-power projects (solar plants, wind farms) in order to buy and sell clean electricity and reduce its carbon footprint. Ultimately, the goal is to send more clean power into the local grids near its data centers, “greening” the cloud infrastructure.<sup>54</sup> In the meantime, the company has taken their role as infrastructure provider to new heights, adding *literal* power to the array of global platforms, services, and data centers they provide in order to keep the cloud functional, on their own terms.

The North Carolina “data center corridor,” which runs through about seven rural western counties between Charlotte and Asheville, is another case in point highlighting the evolving relationship between infrastructure and energy politics. With major sites owned by Google, Apple, Facebook, Disney, and AT&T, among others, it has emerged as a major hub for cloud infrastructure.<sup>55</sup>

In addition to the tax breaks offered by the economically depressed state, there is an abundance of low-cost power, water for cooling, and a climate that allows for “free cooling” most of the time. However, North Carolina has one of the “dirtiest” electrical grids in the country: it only gets 4 percent of its electricity from renewable sources such as solar, wind, or water; coal and nuclear provide 61 percent and 31 percent of the state’s power, respectively. Data centers as an industry have become increasingly targeted by environmental activists for their enormous consumption of (nonrenewable) energy, and as a result, there has been a marked attempt by major cloud-computing companies such as Facebook, Google, and Amazon to promote their cloud infrastructure as embracing clean, green power.

Facebook’s newest data center in Luleå, Sweden, is powered entirely by hydroelectric energy. The company has also added detailed pages on their carbon and energy impact, as well as real-time graphic representations of its power and water usage for two data centers in Oregon and North Carolina. The “dashboards” monitor and visualize the centers’ Power Usage Effectiveness (PUE) and its Water Usage Effectiveness on dedicated Facebook pages.<sup>56</sup> Apple has gone beyond visualizing their energy usage to pioneering efforts to engineer their own clean energy for their data centers in North Carolina and beyond. In 2012 the company built the world’s largest privately owned solar-panel farm to power their Maiden, North Carolina, data center, and they are currently working on another for their facility in Reno, Nevada. Apple’s stated goal is to use 100 percent renewable energy at all of their data centers, and by the end of 2012 they were 75 percent there.<sup>57</sup> According to Google’s website, roughly one-third of the power the company uses to power its data centers is clean power.<sup>58</sup>

In addition to these digital media industry giants taking on power generation, they are also privatizing the infrastructure for data centers, even those that serve the public sector. Amazon Web Services hosts cloud services for the CIA, the Department of Defense, and the Federal Reserve, to name a few major government clients. Infrastructure so critical to the functioning of our society being privatized and consolidated in the hands of a few major providers has serious potential to end up like the market for ISPs: highly concentrated, consolidated, largely unresponsive to consumer demand or regulators, and operating well outside the parameters of what could ever be labeled “in the public interest.” Unmitigated concentration of course also brings with it severe global economic, legal, and political consequences for the free flow of data around the world. Additionally, it begins to invite more centralization of infrastructural authority, which is a troubling move in the direction away from the original end-to-end architectural principle of the Internet.

## Mapping the Cloud

Speaking of digital media infrastructure involves imaginaries as much as topologies. Put differently, and by taking up a distinction introduced by media archeologist Wolfgang Ernst, it involves speaking of signs as much as of signals: an assessment both of our networks' semantic surfaces and of the data traffic itself.<sup>59</sup> Concerns about the sustainability of infrastructure are thus reflected in the overly stylized representations of data centers as much as they are embodied in the Internet's architecture. While the "data about the data" and the visibility created around newly built data centers are meant to mark a turn away from the old days of resource-inefficient corporate client-server computing and toward the net as global public utility,<sup>60</sup> data traffic itself tells different stories. As a complex engineered system, the Internet includes material, technological, and entrepreneurial arrangements through which telecommunications and ISPs manage flows of traffic.<sup>61</sup> Turning to the Internet's architecture, we have to differentiate between three different levels in order to identify how and where this flow of data gains political (and environmental) implications. The most obvious layer of Internet architecture consists of overlay networks such as the World Wide Web, email, or peer-to-peer. Beyond that is the interdomain level; the Internet is made up of tens of thousands of loosely connected networks called Autonomous Systems (AS) employing different business models and profiles (so-called Tier 1 providers, retail services, business services, network access, Web hosting, and the like). The third layer of architecture is the Internet's physically meaningful topology, that is, the way it builds connectivity at the router level.<sup>62</sup>

Since it is difficult to assess the relational dimension of digital media infrastructure for a large and diverse country like the United States, we instead turn to a "small world"<sup>63</sup> like Sweden to elaborate on this issue. Sweden suggests itself as a case in point not only because of its media ecology's limited size but also because of the country's above-standard broadband penetration and the fact that streaming video currently dominates data traffic.<sup>64</sup> Apart from being integrated into services such as Facebook or Google, video can be accessed through on-demand platforms, and its ubiquity accounts for a major change in digital media infrastructure when it comes to the first or "user plane" of the Internet. Sweden is indicative of a global overprovision of over-the-top (OTT) video on-demand services, offering non-authorized but culturally accepted streaming (for example, *sweafilmer.com*) and downloading (The Pirate Bay) platforms alongside digital public service broadcasting (SVT Play) and advertising-based, transactional, or subscription streaming services (Netflix, Viaplay, Voddler,

iTunes, and the like). In addition, telco operators such as ComHem or Telia-Sonera provide various Internet protocol television (IPTV) options. This leads to an overprovision not only in terms of accessing services but also, and more important in this context, in terms of the data that is made accessible.

All of the (legal) video platforms have to make content licensing deals with the very same content providers for the very same titles, which then are encoded, stored, and delivered to customers in as many as thirty-two versions per title (as in the case of Netflix), reflecting requests on varying encoding rates, device types (smartphones, tablets, and so on) and Digital Rights Management (DRM) schemes, the latter depending on territorial licensing agreements. A company like Netflix, for instance, which has gained a strong foothold in Sweden, streams one billion hours of content per month to more than 37 million subscribers globally that view it on hundreds of different device types.<sup>65</sup> Given the competition for attention and the streaming costs involved, streaming service providers in Sweden operate with very low to non-existent margins, while a large share of the data they traffic is *redundant*. Traffic is redundant because of the above-described overprovision of identical titles in numerous shapes and by various providers, but also because redundancy is deliberately created by providers in order to ensure the quality of experience in watching any one of their titles. While part of this redundant traffic is necessary to manage varying bandwidths, streaming delay, packet loss, or server failures,<sup>66</sup> a large part of it is indeed unnecessary, wasting network bandwidth and over-utilizing server-side resources.<sup>67</sup> In short, seen from its user end, the “cloud” looks like a pipeline plugged with often inessential and even progressively devalued data—or, in Marc Andrejevic’s words, like “an environment of data glut.”<sup>68</sup>

While there is limited use in a “close reading” of the router-level or “data plane” of digital media infrastructure in the context of this chapter—that is, of the physical nodes and connections between which data is forwarded based on trafficking policies—a closer look at the secondary or inter-domain level of infrastructure is instructive for assessing the implications of what we have described above. For it is this inter-domain level or “control plane” that configures organizational routing policy—the policies based on what data are sent through the pipes. Data trafficking policy is configured on the inter-domain level either through customer-provider or peering links. To use Sweden as an example, a so-called Tier 1 network provider like TeliaSonera—one of the largest ISPs globally in terms of traffic volume, routes, and autonomous systems inside the network—can provide Internet access at monetary costs similar to a smaller network such as CDNetworks, a content delivery network (CDN) designed to improve the quality of streaming online video. This is called a

customer-provider link. Peering links, on the other hand, are bilateral agreements between two AS networks to exchange certain types of traffic free of charge.<sup>69</sup> For instance, in the Swedish case Netflix rents rackspace at neutral local data centers, connecting those servers via so-called IXPs (Internet exchange points, such as Netnod) and employing peering agreements to smaller Swedish broadband or mobile network operators such as ComHem, Bredbandsbolaget, and the like. This way, more than 80 percent of Netflix's data traffic is served from the local Internet service provider's data center, saving the company transit, transport, and other upstream scaling costs.<sup>70</sup> Customer-provider and peering links thus have inherently different business models and trafficking policies.

Even such a cursory description of one smaller European country's infrastructure for video streaming reveals that one indeed needs a relational perspective in order to understand what infrastructure is about. First and most obviously, data centers are merely one element among many; they do not form the one central node in the network from which to unravel digital distribution's mysteries. Second, common concerns about ownership or cultural hegemony obscure rather than enlighten what is critical about digital media infrastructure. Instead of speculating about "the control from one single country over most of the Internet services," as former Pirate Bay spokesman and Internet activist Peter Sunde recently did,<sup>71</sup> we might study the bilateral agreements between foreign and home-grown Internet services, or the way a platform like Netflix is both culturally and technologically *embedded* in Sweden. For why would Swedish ISPs be interested in peering agreements with Netflix? Because Netflix helps them "push the pipe," and, perhaps even more important, because it creates "added value" to their broadband services. When it comes to the political economy of digital infrastructure, we need to look at its specific topology. In order to find out what the policies of streaming video are about, we have to ask: What need is this infrastructure addressing? How does it engineer a solution, and to which problem?

While video streaming technologies are widely marketed as enhancing consumer control over the entertainment-viewing experience ("anytime, anywhere"), their purpose, as it becomes observable on infrastructural level, is primarily to enhance entrepreneurial control over content. Streaming is a technology that allows content providers to "keep" the file rather than distributing it for permanent storage on consumer devices. Control over content is an issue when major autonomous systems such as TeliaSonera push on the digital market themselves by offering content delivery through IPTV and set-top boxes.<sup>72</sup> Control over content pertains to attempts by platforms such as Netflix or Voddler

to gain independence from content delivery networks and telco companies by purpose-building their own delivery architectures.<sup>73</sup> Yet this striving for control over information is hardly new, nor is it a strategy solely exerted by private companies at the expense of public utility. In fact, the most important Scandinavian player on inter-domain level, TeliaSonera, is largely state owned. As James Beniger documented decades ago in his monumental study, *The Control Revolution* (1986), there is more continuity than cleavage in the relationship of today's information society to the past.

\* \* \*

While data centers (and their public profiles) have been rapidly expanding, the actual infrastructure for media's future still remains woefully insufficient. It is proliferating, but not as fast as the data it is designed to contain, process, and distribute. This problem has been characterized by experts as a “race between our ability to create data and our ability to store and manage data.”<sup>74</sup> This race will be one of the true “technological dramas” that will be playing out in the coming years, as our global media culture is increasingly dependent on streaming, remote storage, and mobile access. To understand and explain the many consequences—sociocultural, economic, political, regulatory, and otherwise—of this growing infrastructure gap will require analyses and scholarship that engages with more than the material dimensions of infrastructure; indeed, the politics of representation, technology policies, industrial practices, and even **the imaginary, abstract constructions of technologized spaces** will all be a part of bridging—and visualizing—this gap moving forward.

## Notes

The authors wish to thank Kurt-Erik Lindquist (Netnod) and Chris Baumann for helpful suggestions, and the anonymous reviewers for critical comments on an earlier draft on this paper.

1. Google website, “Data Centers,” available at <http://www.google.com/about/datacenters> (accessed November 27, 2013).

2. See <http://www.apple.com/environment/renewable-energy> (accessed November 27, 2013).

3. See <https://www.facebook.com/PrinevilleDataCenter> for one example, or <http://www.globalfoundationservices.com/> for Microsoft (accessed November 27, 2013).

4. “Effectively Minimizing Redundant Internet Streaming Traffic to iOS Devices,” available at <http://www.bahnhof.net/gallery> (accessed November 27, 2013).

5. See, for instance, Douglas Alger's book *The Art of the Data Center* (New Jersey: Pearson Education, 2013); the documentaries *Bundled, Buried and Behind Closed Doors* (Mendelsohn, 2011) and *The Bucket Brigade* (Mick, 2012); or Andrew Blum's *Tubes: A Journey to the Center of the Internet* (New York: HarperCollins, 2012).

6. Peter Jakobsson and Fredrik Stiernstedt, "Time, Space and Clouds of Information: Data Center Discourse and the Meaning of Durability," in *Cultural Technologies: The Shaping of Culture in Media and Society*, ed. Göran Bolin (New York: Routledge, 2012), 103–18. See also Peter Jakobsson and Fredrik Stiernstedt, "Googleplex and Informational Culture" in *Media Houses: Architecture, Media, and the Production of Centrality*, ed. Staffan Ericsson and Kristina Riegert (New York: Peter Lang, 2014), 112–32.

7. Wakefield Research, "Citrix Cloud Survey," August 2012, 1, available at [http://www.citrix.com/content/dam/citrix/en\\_us/documents/go/Citrix-Cloud-Survey-Guide.pdf](http://www.citrix.com/content/dam/citrix/en_us/documents/go/Citrix-Cloud-Survey-Guide.pdf) (accessed November 27, 2013).

8. Culture Digitally Blog, post by Casey O'Donnell at <http://www.marco.org/2013/07/03/lockdown> (accessed November 27, 2013).

9. Bryan Pfaffenberger, "Technological Dramas," *Science, Technology and Human Values* 17, no. 3 (Summer, 1992): 285; compare with Finn Brunton, *Spam: A Shadow History of the Internet* (Cambridge, Mass.: MIT Press, 2013), xvi.

10. Josh Braun, "Going over the Top: Online Television Distribution as Sociotechnical System," *Communication, Culture and Critique* 6 (2013): 432–58.

11. Bahnhof website, <http://www.bahnhof.net/wikileaks> (accessed November 27, 2013).

12. Bahnhof website, <http://www.bahnhof.net/basedinsweden> (accessed November 27, 2013).

13. Jan van Dijk, *The Network Society* (Thousand Oaks, Calif.: Sage, 2012), 79.

14. See <http://www.wired.com/wiredenterprise/2012/03/google-miner-helmet> (accessed November 27, 2013). Google's public relations team denied all requests for interviews about their data centers for this chapter.

15. Jonathan Sterne, *mp3: The Meaning of a Format* (Durham, N.C.: Duke University Press, 2012), 209, 219.

16. Bruno Latour, "On Technical Mediation," *Common Knowledge* 3, no. 2 (1994): 29–64; see also Bruno Latour, *Pandora's Hope: Essays on the Reality of Science Studies* (Cambridge, Mass.: Harvard University Press, 1999).

17. Compare with Braun's notion of "transparent intermediaries" (2013), which seems less useful here, however, as it relates transparency primarily to white label platforms/services.

18. Lisa Parks, "'Stuff You Can Kick': Toward a Theory of Media Infrastructures," in *Humanities and the Digital*, ed. David Theo Goldberg and Patrik Svensson (Cambridge, Mass.: MIT Press, 2015), 355–73.

19. Lisa Parks, "Where the Cable Ends: Television in Fringe Areas," in *Cable Visions: Television Beyond Broadcasting*, eds. Sarah Banet-Weiser, Cynthia Chris, and Anthony Freitas (New York: New York University Press, 2006), 124.

20. Jussi Parikka, "Critically Engineered Wireless Politics," *Culture Machine* 14 (2013): 1–26.

21. Susan Leigh Star and Martha Lampland, eds., *Standards and Their Stories: How Quantifying, Classifying and Formalizing Practices Shape Everyday Life* (Ithaca, N.Y.: Cornell University Press, 2009).

22. Parikka, "Critically Engineered Wireless Politics," 164.
23. Quoted in Blum, *Tubes*, 239.
24. Lisa Parks, "Around the Antenna Tree: The Politics of Infrastructural Visibility," *Flow*, March 6, 2009, available at <http://flowtv.org/2009/03/around-the-antenna-tree-the-politics-of-infrastructural-visibility> (accessed November 27, 2013).
25. See, for instance, Horace Newcomb, "Toward Synthetic Media Industry Research" in *Media Industries: History, Theory, and Method*, ed. Alisa Perren and Jennifer Holt (Chichester: Wiley-Blackwell, 2009), 264–71.
26. For more on these fundamental questions related to media markets, see David Hesmondalgh, *The Cultural Industries* (London: Sage, 2013); Jeff Chester, *Digital Destiny* (New York: New Press, 2007); Des Freedman, "Outsourcing Internet Regulation," and "Web 2.0 and the Death of the Blockbuster Economy," in *Misunderstanding the Internet*, ed. James Curran, Natalie Fenton, and Des Freedman (New York: Routledge, 2012), 69–94, 95–120; Terry Flew, *The Creative Industries* (Los Angeles: Sage, 2012); Sean Cubitt, "Distribution and Media Flows," *Cultural Politics* 1, no. 2 (2005), 193–214; Arthur de Vany, *Hollywood Economics: How Extreme Uncertainty Shapes the Film Industry* (London: Routledge, 2004); Harold Vogel, *Entertainment Industry Economics: A Guide for Financial Analysis* (Cambridge: Cambridge University Press, 2010).
27. Benjamin Compaine and Douglas Gomery, *Who Owns the Media? Competition and Concentration in the Mass Media Industry* (London: Erlbaum, 2000), 523. See also Ithiel de Sola Pool, *Technologies of Freedom* (Cambridge, Mass.: Harvard University Press, 1983); Robert McChesney, *Digital Disconnect* (New York: New Press, 2013); Susan Crawford, *Captive Audience* (New Haven, Conn.: Yale University Press, 2013).
28. Mark Fowler, quoted in David Croteau and William Hoynes, *The Business of Media: Corporate Media and the Public Interest* (New York: Pine Forge, 2006), 25.
29. Lev Manovich, "Cultural Analytics: Visualizing Cultural Patterns in the Era of 'More Media,'" in *Domus* (Milan, 2009); for the notion of overflow, see Michel Callon, "An Essay on Framing and Overflowing: Economic Externalities Revisited by Sociology" in *On Markets*, ed. John Law (Oxford / Keele: Blackwell / Sociological Review, 1998), 244–69.
30. Richard Maxwell and Toby Miller, *Greening the Media* (Oxford: Oxford University Press, 2012); Nadia Bozak, *The Cinematic Footprint: Lights, Camera, Natural Resources* (New Brunswick, N.J.: Rutgers University Press, 2012); Sean Cubitt, Robert Hassan, and Ingrid Volkmer, "Does Cloud Computing Have a Silver Lining?" *Media, Culture and Society* 33, no. 1 (2011): 149–58 and elsewhere.
31. See Vogel, *Entertainment Industry Economics*, 528, for a list of conventional policy issues; compare with Croteau and Hoynes, *Business of Media*, 25.
32. Sandra Braman, "Where Has Media Policy Gone? Defining the Field in the Twenty-First Century," *Communicaiton Law and Policy* 9, no. 2 (Spring 2004): 156, 159.
33. See, for instance, Jack Goldsmith and Tim Wu, *Who Controls the Internet? Illusions of a Borderless World* (Oxford: Oxford University Press, 2006).

34. Geoffrey C. Bowker, Karen Baker, Florence Millerand, and David Ribes, "Toward Information Infrastructure Studies: Ways of Knowing in a Networked Environment," in *The International Handbook of Internet Research*, ed. Jeremy Hunsinger, Lisbeth Klastrup, and Matthew Allen (Heidelberg: Springer, 2010), 97–117.

35. Star and Lampland, *Standards and Their Stories*, 17.

36. Brian Larkin, "The Politics and Poetics of Infrastructure," *Annual Review of Anthropology* 42 (2013): 329.

37. *Ibid.*, 333.

38. *Ibid.*, 335.

39. Compare with Lewis Mumford, *Technics and Civilization* (Chicago: Chicago University Press, 2010).

40. Larkin, *Politics and Poetics*, 335.

41. Persuasive design has mostly been propelled by computer technologies engineering user behavior, such as prescriptive social software like Brightkite or Loopt. See Alice E. Marwick, "Foursquare, Locative Media, and Prescriptive Social Media," 2009, available at <http://www.tiara.org> (accessed November 27, 2013).

42. Nasuni, "The State of Cloud Storage 2013 Industry Report," available at [http://www6.nasuni.com/rs/nasuni/images/2013\\_Nasuni\\_CSP\\_Report.pdf](http://www6.nasuni.com/rs/nasuni/images/2013_Nasuni_CSP_Report.pdf), and "Comparing Cloud Storage Providers in 2013," infographic, available at [http://www.nasuni.com/blog/193-comparing\\_cloud\\_storage\\_providers\\_in](http://www.nasuni.com/blog/193-comparing_cloud_storage_providers_in) (accessed November 27, 2013).

43. Star and Lampland, *Standards and Their Stories*, 11.

44. Matthew Fuller and Andrew Goffey, *Evil Media* (Cambridge, Mass.: MIT Press, 2012), 58.

45. See Jennifer Holt, "Regulating Connected Viewing," in *Connected Viewing: Selling, Streaming and Sharing Digital Media*, ed. Jennifer Holt and Kevin Sanson (New York: Routledge, 2013), 19–39; and Primavera De Filippi and Smári McCarthy, "Cloud Computing: Centralization and Data Sovereignty," *European Journal for Law and Technology* 3, no. 2 (2012), available at <http://ejlt.org/article/view/101/234> (accessed November 27, 2013).

46. See, for example, Stacey Higginbotham, "Video Isn't Breaking the Internet: The Industry Giants Are," *GigaOm*, September 16, 2013, available at <http://gigaom.com/2013/09/16/video-isnt-breaking-the-internet-the-industry-giants-are> (accessed November 27, 2013).

47. Rich Miller, "Google's Infrastructure Boom Continues: Expansion Ahead in Oregon," *Data Center Knowledge*, April 24, 2013, available at <http://www.datacenterknowledge.com/archives/2013/04/24/googles-infrastructure-boom-continues-expansion-ahead-in-oregon> (accessed November 27, 2013).

48. Quoted in James Glanz, "Power, Pollution and the Internet," *New York Times*, September 22, 2012, available at [http://www.nytimes.com/2012/09/23/technology/data-centers-waste-vast-amounts-of-energy-belying-industry-image.html?smid=tw-share&pagewanted=all&\\_r=1&](http://www.nytimes.com/2012/09/23/technology/data-centers-waste-vast-amounts-of-energy-belying-industry-image.html?smid=tw-share&pagewanted=all&_r=1&) (accessed November 27, 2013).

49. Quoted in Gary Cook, “How Clean Is Your Cloud?” *Greenpeace International*, April 2012, 10, available at <http://www.greenpeace.org/international/Global/international/publications/climate/2012/iCoal/HowCleanisYourCloud.pdf> (accessed November 27, 2013).

50. See Glanz, “Power, Pollution and the Internet”; and Cubbitt, Hassan, and Volkmmer, “Silver Lining,” 154.

51. Glanz, “Power, Pollution and the Internet.”

52. Cook, “How Clean,” 23.

53. Google’s server farms are all over the United States, as well as in Canada, Germany, The Netherlands, France, the United Kingdom, Italy, Russia, Brazil, Tokyo, Beijing, and Hong Kong. See <http://www.datacenterknowledge.com/archives/2012/05/15/google-data-center-faq> (accessed September 20, 2014).

54. See Uclia Wang, “Google the Power Player Invests in Another Giant Solar Farm,” *Forbes*, October 10, 2013, available at <http://www.forbes.com/sites/uciliawang/2013/10/10/google-the-power-player-invests-in-another-giant-solar-farm> (accessed November 27, 2013).

55. See Katie Fehrenbacher, “10 Reasons Apple, Facebook, and Google Chose North Carolina for Their Mega Data Centers,” *Giga Om*, July 10, 2012, available at <http://gigaom.com/2012/07/10/10-reasons-apple-facebook-google-chose-north-carolina-for-their-mega-data-centers> (accessed November 27, 2013).

56. The visualization for Facebook’s Prineville, Oregon, center can be found at [https://www.facebook.com/PrinevilleDataCenter/app\\_399244020173259](https://www.facebook.com/PrinevilleDataCenter/app_399244020173259) (accessed November 27, 2013). The Forest City, North Carolina, data center can be found at [https://www.facebook.com/ForestCityDataCenter/app\\_288655784601722](https://www.facebook.com/ForestCityDataCenter/app_288655784601722) (accessed November 27, 2013). The page detailing the company’s carbon and energy impact can be found at [https://www.fb-carbon.com/pdf/FB\\_carbon\\_eneergy\\_impact\\_2012.pdf](https://www.fb-carbon.com/pdf/FB_carbon_eneergy_impact_2012.pdf) (accessed November 27, 2013).

57. Apple owns only four data centers at this writing: Maiden, North Carolina; Prineville, Oregon; Newark, California; Reno, Nevada; there are reports of a Hong Kong facility being built. Achieving 100 percent renewable energy is a much smaller, albeit significant, task than it would be for a company like Google. See “Worldwide Renewable Energy Use at Apple” graph, Apple and the Environment website, <http://www.apple.com/environment/renewable-energy> (accessed November 27, 2013).

58. Google website, “Green,” <http://www.google.com/green/bigpicture> (accessed November 27, 2013).

59. Wolfgang Ernst: “Between Real Time and Memory on Demand: Reflections on/of Television,” *South Atlantic Quarterly* 101, no. 3 (Summer 2002): 627–28.

60. One should not forget that today’s data centers are related to, if not caused by, another energy problem: the increasing power costs of data centers *within* corporate environment or even industrial sectors, and the overbuilding of IT assets in every industry sector. See Nicholas Carr, *The Big Switch: Rewiring the World, from Edison to Google* (New York: Norton), 56.

61. Paul Dourish and Genevieve Bell, "The Infrastructure of Experience and the Experience of Infrastructure: Meaning and Structure in Everyday Encounters with Space," *Environment and Planning B: Planning and Design* 34 (2007): 416.

62. This definition roughly correlates with a common computer science distinction between data plane and control plane, and we are aware of that difference in our terminology.

63. In the sense of Jeffrey Travers and Stanley Milgram, "An Experimental Study of the Small World Problem," *Sociometry* 32, no. 4 (1969): 425–43.

64. See Patrick Vonderau, "Beyond Piracy: Understanding Digital Markets," in *Connected Viewing: Selling, Streaming, and Sharing Media in the Digital Era*, ed. Jennifer Holt and Kevin Sanson (New York: Routledge, 2013), 99–123. Thanks to Kurtis Lindqvist (Netnod.se, Sweden) for additional information on Sweden's digital infrastructure.

65. Nina Hjorth Bargisen (European network strategy manager for Netflix), presentation given at the Netnod Members Meeting, 2013.

66. Sanjoy Paul, *Digital Video Distribution in Broadband, Television, Mobile and Converged Networks. Trends, Challenges and Solutions* (Chichester: Wiley, 2011), 53.

67. Yao Liu, Fei Li, Lei Guo et. al., "Effectively Minimizing Redundant Internet Streaming Traffic to iOS Devices," *IEEE Transactions on Multimedia* (2013), available at <http://www.cs.binghamton.edu/~yaoliu/publications/infocom13-range.pdf> (accessed November 27, 2013).

68. Andrejevic, 41.

69. Compare with Dourish and Bell, "Infrastructure," 416; they define common carrier and bilateral peering as "arrangements through which telecommunications and Internet service providers manage flows of traffic."

70. Bargisen, presentation.

71. Peter Sunde (brokep), "Intertubes," available at <http://blog.brokep.com/2013/05/26/intertubes> (accessed November 27, 2013).

72. Backed by private equity group EQT, TeliaSonera currently aims to gain control over Swedish telecommunication operators and to establish itself as an infrastructural gatekeeper. See Per Lindvall, "Låt staten ta hand om nätkontrollen," *Svenska Dagbladet*, February 3, 2014.

73. Vodddler, for instance, uses its own patented streaming solution VodddlerNet, while Netflix has built up its own content delivery network, OpenConnect.

74. Quoted in Glanz, "Power, Pollution and the Internet."