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Research Article

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The making of critical data center studies

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Abstract

In this article, the authors demonstrate how the data center has become a key site, object, and metaphor for interdisciplinary scholarship of the internet. While the data center is a fabrication of engineering, computer science, and cognate fields, it has been the critical gaze of scholars outside of those industries. Together, this scholarship has established the field of Critical Data Center Studies. Critiques of the data center – often thought of more generally as 'internet infrastructure', and more evocatively as 'the cloud' – have emerged from the social sciences, humanities, journalism, and the arts. The authors do this by answering questions about the current social, cultural, political, and environmental landscapes of the data center. Scrutiny of the foundational imaginaries of the internet, real estate deals by Big Tech, the industry's enabling policies, their connections to energy and other public infrastructure – among many other factors – serves, at the very least, to situate the data center as a media object, as more than simply a material infrastructure, as more than data warehouse, and as more than 'the cloud'. Further to this, the authors reflect on how the data center has been and continues to be studied, and why critical interventions have been so fruitful within a vast array of disciplines – from history and anthropology, to media studies, information studies, and science & technology studies – for shifting the focus from questions of infrastructural visibility to questions that weave together concerns of efficiency, policy, popular culture, and planetary devastation.

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Introduction

The data center has emerged as a site for critical inquiry into the materialities of the internet, the cloud, and digital technologies. As massive server farms and warehouses that literally house the cloud, data centers make visible the physical infrastructure enabling our digital lives. In recent years, researchers across the disciplines have increasingly studied data centers – their locations, architectures, social and environmental impacts, labor conditions, and more – to understand the politics and ecologies of data and computation. This growing body of scholarship constitutes an interdisciplinary field of what we are calling 'Critical Data Center Studies' that examines the data center as both an object of study and conceptual anchor point.

In this article, we aim to track the development of Critical Data Center Studies and synthesize key concepts, methodologies, and trajectories that have defined the field so far, and apart from Platform Studies, Code Studies, and Internet Studies (etc). We argue that approaching data centers from a humanistic (feminist and decolonial) perspective reveals how data infrastructures exist in tension with local histories, environments, communities, and publics. Data centers take shape through specific relationships and promises about the future, not as inevitable or unmalleable technical systems.

The article begins by outlining three overarching questions that have oriented critical data center research: What are data centers? Where are they located and why? How have scholars in the field examined them? Next, we develop a conceptual framing of data centers as constantly shifting 'relational assemblages', materializations of particular power relations and imaginaries. We historicize early notions of the 'data center' in the 20th century as statistical information warehouses. Our article then surveys popular taxonomies of data centers today – enterprise, cloud, hyperscale – and their limitations, pointing to emerging structural diversities. In the central analysis, we detail the 'promises' and rationalities underlying where major data centers are built – especially political, climatic, and infrastructural promises used to justify data center expansion. Here we synthesize key scholarship demonstrating how data centers intersect with local histories and environments. We conclude by proposing future research trajectories for Critical Data Center Studies, such as tracking conceptual evolution of 'the data center', foregrounding labor and maintenance, and interrogating the materialities of 'AI' and new digital developments.

Articulating Critical Data Center Studies as a distinct field in the making has both practical and political aims. In other words, there is practical value in identifying a set of work that seeks to untangle, narrativize, or unsettle how data centers have emerged and why. Perhaps more important than the practical work of naming and assembling a coherent interdisciplinary field, however, entails articulating the shared political commitments for doing this work. By insisting that data centers are not natural or inevitable infrastructural objects, we find that Critical Data Center Studies is more invested in following how data centers have been legitimized, built, and expanded through overlapping material-discursive practices. These include, for example, settler-colonial logics that perceive land, water, and energy as manageable 'resources' and market logics that justify unending growth through façades of sustainability. We are interested in how the effects of data center growth and maintenance can be articulated through, for example, feminist approaches to materiality

(Hogan, 2015), DIY and community activism (Lehuedé, 2022; Pasek, 2023), and frameworks attuned to coloniality and extraction (Hogan, 2018; Johnson, 2019).

Ultimately, we present Critical Data Center Studies as a coherent interdisciplinary field while highlighting areas for continued geographic, topical, and methodological diversity. This provides a valuable conceptual scaffolding and literature review for scholars, journalists, activists, and artists interested in the politics of internet infrastructure and cloud imaginaries. It also gives an analytical lens to approach data centers not as neutral technical objects, but as contested sites of power, capital, and imagination.

Data centers in the field

We begin with situating data centers as an object of inquiry by focusing on where scholars are located in their respective (sub)-fields and commitments to particular knowledge systems. In this section, we ask where critical data center scholars locate themselves within disciplinary boundaries. While we track some specific contributions as outgrowths of particular fields, we find that critical data center scholars are often drawing on a range of field knowledges – an assemblage of theories, methods, and methodologies. Our goal in tracking these positions, then, isn't to isolate or foreclose new directions in critical data center studies scholarship; on the contrary, we follow the different field locations of data center scholarship to illuminate productive tensions and areas for future inquiry. As an emergent yet coherent field of study, data center studies needs epistemic multiplicity to ask critical questions about the always in-flux, relational, political, and historical valencies of data infrastructures.

As scholars who are located within disparate disciplinary genealogies ourselves, we find the exercise of locating data center studies within specific yet blurred boundaries to be productive for articulating the vast influence and consequentiality of data center relations. In particular, the following set of field articulations – each with their own messy histories, fuzzy boundaries, and bricoleur traditions – have been central to our in-process understanding of critical data center studies: media studies, infrastructure studies, science and technology studies, anthropology, sociology, digital rhetoric, and, among others, art and aesthetics. We recognize these field conversations are not an exhaustive list of what constitutes data center studies, but rather offer one set of entry points for the critical questions we have staged throughout this article.

Media studies has been central in the making of Critical Data Center Studies. Within media studies, the data center has been a site of inquiry at the intersections of many areas such as environmental media (Cubitt, 2016), media geology (Parikka, 2015), and archival studies (Hogan, 2015). Data centers are sites that bring sharp attention to the material, infrastructural, and elemental dimensions of media. As Starosielski (2019) suggests, 'over the past decade, media studies has become elemental. By this, I mean that the field has become attuned to constituent parts, especially to the substances and substrates that compose media' (para. 2). Within such an understanding of media, researchers can begin articulating the constituent parts of data centers – the rare earths found in the hardware components of servers, the water that is used for cooling the servers, the labor that goes into training the data located on the servers, the power and energy that surges through data centers, the heat exhaust that is amassed from server computation, and so on. As media studies scholars bring data centers into their modes of analysis, political questions emerge about the rapid and ongoing rise of data accumulation in nearly all sectors of public and private life.

Media studies scholars have also attended to the role the data center plays in the distribution and circulation of signal traffic (Cubitt 2016; Holt and Vonderau, 2015; Parks and Starosielski, 2015; Peters, 2015; Starosielski and Walker, 2016). As Lisa Parks and Nicole Starosielski note, the data

center is one infrastructural node among many others (including fiber optic networks, landing stations, and mobile phone towers) that traffic massive flows of data across time and space. Data centers have become a site of scholarly inquiry not only because of central role they play in the circulation of signal traffic, but because of the materialities (Hogan, 2015; Hu, 2015; Maxwell and Miller, 2012; Starosielski, 2016), energies (Pasek et al., 2023), minerals (Crawford, 2021; Taffel, 2018), and land (Burrington, 2020; Duarte, 2017; Hogan, 2018) needed to sustain the build out of more data centers and information and communication technologies. In following these areas of concern scholars have articulated the social, environmental, and political ramifications of the data center industry.

In addition to work in media studies, an allied area of inquiry where data center studies finds disciplinary support is infrastructure studies or critical infrastructure studies. For Brian Larkin (2013), infrastructures are 'matter that enable the movement of other matter' (329). In this way, we can certainly understand data centers as particular configurations of matter that help facilitate the movement of data. But, as many infrastructure scholars remind us, infrastructure is not built and maintained outside of particular political circumstances. Infrastructure is consequential, holding particular meaning depending on the relation one has to it. Infrastructure can sustain life in one instant and deal out conditions of premature death in another. We can understand data center infrastructure in similar ways: not inherently bad or good, but as carrying different consequences depending on where you are located. Data center scholars use an infrastructural disposition to study the data center landscape, which places attention on issues such as 'cloud' design and public imaginaries (Carruth, 2014; Holt and Vonderau, 2015; Mosco, 2014), the relationship between public goods and private capital (Brodie, 2020), and the entanglement of the state and the data center industry (Vonderau, 2019a).

Researchers from the humanities and social sciences have examined data centers from a number of vantage points. Anthropological studies have shown how data center growth and expansion are often tethered to colonial and imperialist projects. For example, Steven Monserrate Gonzalez (2022; and with Sean Mallin, 2023) has done extensive ethnographic work studying data center infrastructure in post-Hurricane Maria in Puerto Rico, and Johnson's (2019) work on Iceland's data center industry brings to light how data center developers position the remote, 'wild' land of Iceland as fertile ground that can be harnessed for profit and extraction, for the construction of digital infrastructure. Johnson locates this positioning as an outgrowth of a longer imperial history where place, nature, and land are seen as resources to be managed. Sociological accounts have placed data center development within larger historical, social, and economic contexts. For example, Burrell's (2020) study of Facebook's data center in Prineville, Oregon describes the Prineville data center construction not as a last-minute deal struck between naive locals and all-powerful tech company, but as 'situated in a much longer local struggle over rural development, recovery, and revival in the wake of dwindling natural resource industries' (286).

Researchers located in digital rhetoric and communication studies have also examined the significance of data centers in research, theory, and practice. Digital rhetoric has experienced its own infrastructural and ecological turn, which has driven scholars to follow how data centers are entangled with digital communication. For instance, data centers enter into Christian Pulver's (2020) analysis of the materiality of digital writing, which, he argues, is a deeply inscriptive and global process supported by data center infrastructure. Paying particular attention to how Facebook's New Mexico data center intersects with stories of land, settler colonialism, and resource extraction, Edwards (2020) has pointed out how digital rhetoric is never too far removed from conditions of damage. Not only is digital rhetoric research well poised to continue investigating these infrastructural and ecological connections between data centers and digital communication,

but researchers can also interrogate how the industry is often justified through modes of public address.

While each of these lines of thinking aim to make interventions in distinct disciplines, we emphasize again that these boundaries are more porous and that Critical Data Center Studies is an increasingly interdisciplinary endeavor. Our own collaboration for this article is a testament to this claim, and we find the stakes of our work are made sharper through such collaborations. At its best, the work of Critical Data Center Studies moves from a set of scholarly concerns about definition and location to address the urgencies felt in communities where data centers are being built. Recent work amplifying 'data center activism' (Cappella, 2023; Lehuedé, 2022) in sites such as Chile, Ireland, the Netherlands, and the US attest to such urgencies. To this end, researchers are seeking alternative modes of addressing publics outside of 'traditional' publication realms. For instance, Anne Pasek's (2023) digital zine 'Getting into Fights with Data Centers' circulates without a paywall, providing analysis of the material, political, and environmental effects of data centers, gesturing toward examples of anti-data center development efforts, and posing an argument to readers about why to engage in conversations about 'how we can stop the next data center from being built' (6). Similarly, the Environmental Media Lab circulates an open bibliography entitled 'Critical Data Center Studies' which can be used by anyone to learn from and build upon the interdisciplinarity of the field.

What are data centers?

'The cloud' is a story we are told about how data is moved and stored in the early-21st century. The material anchor of this 'cloud' narrative is the data center. The story tells us that the data center is foundational to digital life and that it has become a site of speculation about digital living. But what, exactly, is a *data center*? What should it be? What could it be?

Part of what we hope to offer in this article is a methodological synthesis for accounting for data centers (and their associated peripheries) through humanistic, feminist, and decolonial lenses. Building from Holt and Vonderau's (2015) work on the 'relational perspective' of data centers, we situate the data center not necessarily as a place or object, but more as a relationship – or rather, a constantly shifting assemblage of relationships, *objectified* in particular ways, in particular places. Understanding the data center as relational, or as a set of relationships, brings into relief many of the core tenets of Critical Data Center Studies (e.g., (in)visibility and (in)accessibility (Carruth, 2014; Mayer, 2019), the politics of energy and water use (Hogan, 2015; Vonderau, 2019), and material impact on the largely rural regions where they are located (Vonderau, 2019)), while also foregrounding important future directions for the field, such as deeper inquiries into data center hardware and logistics (Cooper, 2021), maintenance and labor (Brodie and Velkova, 2021; Mayer and Velkova 2023), as well as land and real estate (Greene, 2022). Crucially, approaching data centers as relational pushes Critical Data Center Studies beyond the sites of data centers themselves, allowing for deeper engagement with the transnational extractive and logistical infrastructures that support and maintain these sites (Arboleda, 2020).

Precisely what constitutes a data center has changed over time, and continues to shift between regional, legal, political, and environmental contexts. While data centers – commonly understood as massive, sprawling campuses lined with rows of humming servers – are a relatively recent phenomenon that has expanded alongside the rise of 'cloud computing'; and 'Web 2.0', the explicit idea of a data 'center' has a deeper history. The centralization of information processing and distribution has long served as a tool of empire and colonialism (Innis, 2008; Stoler, 2008), but the idea of the data center (as a place distinct from archives, libraries, offices of records, etc.,) emerged out of the

proliferation of statistical information agencies during the Cold War. From the 1950s through the 1990s, the term *data center* (at times used interchangeably with *data bank*) most often referred to government (and later, to a lesser extent, corporate) 'central statistical offices' that incorporated mainframe computing in the collation and organization of records (UCLA Law Review, 1968; Agar, 2003). Many efforts to centralize government information with computers in the 1960s met with fierce opposition and protests over privacy concerns and fears of government overreach. In 1965, the US Social Science Research Council lobbied Congress for the need to create a data center that would link all federal population data, creating a centralized access point for researchers and policymakers. This 'National Data Center' never came to be, but persistent fears about its privacy implications (including allegations of illegal wire-tapping and psychological testing) continued, and led directly to the passage of the 1974 Privacy Act (Kraus, 2011). From its earliest rhetorical incarnations, the idea of the *data center* (the infrastructural consolidation of statistical information) conjured nightmares of privacy violations and gross abuses of power by governments – nightmares that have now taken the form of expansive real estate holdings of information extraction and control, built and maintained sometimes by states (see Hogan, 2015), sometimes by multinational tech companies (see Vonderau, 2017), and sometimes by multinational tech companies on behalf of and in service to states.

During the Cold War, data centers were largely defined by the kinds of data they kept (census data, crime data, labor data, etc.). These were centers for specific types of statistical information processing. This data may have been partially processed and analyzed by mainframe computers, but, as scholars like Mar Hicks (2018; Mullaney et al., 2021) have shown, a majority of the work on and with computerized information during this time was conducted by women, particularly women of color. As such, data centers in the 1960s and 1970s were profoundly human places in which the politics of gender, race, and technology were brought into sharp relief. Today's data centers are far more depopulated, or at least they seem that way. They present as mammoth structural storehouses of digital information, within which narratives and imaginaries of human labor and maintenance tend to vanish in the face of their alleged technological sophistication and architectural vastness – houses for wires, metal, and electricity. As Taylor (2019) writes: 'The end result is an image of a technological landscape emptied of people and any obvious signs of human presence: a mechanized world of techno-wilderness'. This popular image of the data center as a place 'not built for humans' drives how data centers are understood both in popular culture, and by the powerful actors who build, maintain, and regulate them. As Daniel Greene reminds us, however, 'The internet's infrastructure evolved with its landlords'; whether as owners or leasers of the buildings where data centers are housed, landlords strike deals and manage the internet as 'assets'.

Defining a data center in the twenty-first century does not have much to do with the data, or the people working on/with it, but predominantly with the material structure in which the data is held. The data itself is incidental – a given, almost taken for granted.

According to network technology company Cisco, there are three types of 'traditional' data centers: Enterprise (internal corporate data centers, whose users are typically restricted to company employees and clients), Managed Services (similar to Enterprise, but where one company manages the entire data center on behalf of another company), and Colocation (many different companies renting server space in a single data center). In a category unto themselves are Cloud/Hyperscale data centers (off-premises data centers hosted by a cloud services company like Amazon Web Services or Microsoft Azure) (Cisco, n.d). This categorization is common across the industry, and is further subdivided by size. An enterprise data center can be as small as an 'internal server closet' (less than 100 square feet), to over 20,000 square feet, while colocation and cloud data centers can theoretically be as small as a studio apartment, while the largest 'hyperscale' data center in the world

(Switch's The Citadel in Reno, Nevada) covers over seven-million square feet (Shehabi et al., 2016; Taneja, 2020). Research in Critical Data Center Studies tends to focus on cloud data centers and hyperscale projects by big tech companies like Google, Amazon, Microsoft, and Facebook, but many of the largest data centers in the world are colocation data centers managed by less immediately visible companies like Equinix, Switch, and COPT, which is actually more of a 'managed services' company that builds corporate data centers for specific clients, such as the U.S. government (see Burrington, 2014; Greene 2022). These kinds of data centers need more attention. Furthermore, while cloud computing companies currently have about 207 hyperscale data center projects disclosed around the globe, a majority are clustered in just a few regions (predominantly in the United States), and depend heavily on colocation services and internet exchange infrastructure to provide 'on-ramps' to the wider Internet (Telegeography, 2021). By square-footage, colocation data centers are far more prevalent than hyperscale cloud data centers, with an estimated 4799 in active service in 127 countries (Data Center Map, n.d). Future research should more deeply consider the discursive work of data center taxonomies, and how these taxonomies manifest certain visibilities and invisibilities that become refracted in scholarship and policy.

How states grapple with these questions offers some of the most lucid definitional work on data centers as material structures. The US considers data centers quite literally as hot-boxes of information, regulating them as information processing and thermal control entities. Unlike in the 1960s and 70s, current legal definitions of data centers in the U.S. do not deal so much with the data itself, or the actual labor of processing and distribution, but instead are much more closely tied to energy use and heat management practices. According to Title 42, Section 17112 of the U.S. Code (2007), a data center must have 'environmental control equipment to maintain the proper conditions for the operation of electronic equipment'. While heat management is a crucial concern for the industry worldwide, the US inscribes the thermopolitics (Moro, 2022; Starosielski, 2016; Vonderau, 2019) of data centers directly into the U.S. Code, requiring sophisticated temperature regulation in order to be legally classified as a data center. Thus, a building cannot legally be a data center in the US unless it is air conditioned.

In the European Union, regulating data centers is a much more complex, interscalar process that exerts much more influence on the electronic equipment inside the data center, and how it operates. Servers themselves (and the components of those servers) are governed by ecodesign regulations that exist in conversation with, but independently of the codes regulating the building itself (European Commission, 2013). As such, the E.U. does not only regulate the data center as a structure, but also breaks it into the sum of its parts, creating sub-classification schemes for the data center's operational hardware (e.g., *data storage products*, *servers*, *CPUs*, etc.) (European Commission, 2019). The building in this case is incidental, existing as an enclosure that is responsible in some ways (e.g., cooling, electricity delivery), but not in others, for the hardware and data inside. In 2020, many of these regulations were codified into a new set of design and energy efficiency standards for data centers set forth by the European Commission (EN 50,600), and these standards have since been accepted and integrated into the International Standards Organization's (ISO) framework for data centers, meaning that most future data centers worldwide will be built to these standards (Acton, 2020).

Enterprise, *Cloud*, *Hyperscale, Traditional, Mid-Tier, High-End* – these taxonomies are not totalizing, and do not accurately reflect the growing structural diversity of data centers. In fact, data centers have grown so diverse, wily, and unpredictable in form, that industry leaders are developing very particular ideas about what data centers should be, and go to great lengths to maintain categorical boundaries around the 'traditional' data center industry.

For example, an influential 2020 study in the journal *Science* measured global data center energy use across the last decade, but explicitly omitted cryptocurrency mining data centers, largely because the so-called 'traditional data center' industry does not acknowledge cryptocurrency miners as legitimate industry players (see reference data in Masanet et al., 2020). This study shows that data centers consume approximately 1% of the world's electricity. It also illustrates that efficiency has greatly improved over the last decade. This means that much more computing power is now possible for similar amounts of energy. This narrative frames a sort of success story; a tale of engineers improving 'efficiency', and 'greening' the industry by cutting energy costs. And it is a success story, to some degree, but a fundamentally flawed one.

The story of efficiency has proven a popular one. Efficiency has been a boon at a critical time when the adverse environmental impacts of digital technology are more visible than ever (see Miller, 2021; Patrizio, 2020; Sverdlik, 2020). Yet, while Masanet et al. place global data center energy use at about 205 TW-hours/year, the omission of cryptocurrency mining data centers not only obscures a massive amount of energy use (which, by some estimates is 122 TW-hours/year (De Vries, 2021), more than half the total consumption of the 'traditional' industry), it also ignores a key driver of data center evolution and change. While often treated as a fringe practice relegated to hacker garages and repurposed abandoned warehouses, industrial-scale cryptocurrency mining began and continues to thrive inside traditional colocation data centers, where high-density proof-of-work systems model practices for 'specializing the data center' in service of present and future AI and machine learning infrastructures (Magaki et al., 2016; Miller, 2014; Richmond, 2018). Furthermore, as cryptocurrency mining has grown in scale, it has diversified its infrastructure. In certain regions, cryptocurrency mining data centers do not even exist in one place, but are constructed as mobile, modular entities, packed tightly into custom shipping containers, and move where energy is cheapest and most abundant. This practice is increasingly common in Texas, where multiple companies specialize in building and operating modular cryptocurrency mining containers that pull up to natural gas power plants and run off of captured gas flares (Chapa, 2020). While these types of modular data centers may seem strange at first, they closely resemble structural trends in the edge computing space, where modularity, technical simplicity, and thermal efficiency are paramount (see Fulton, 2021). Amazon, too, manages a fleet of mobile data centers (Amazon Snowmobile) that ferry exabytes of data from enterprise to Amazon Web Services cloud data centers.

These mobile data centers on the *edge* (a paradox of geography if there ever was one), moving data not through cables but across asphalt interstates, are coded as part of the 'traditional' data center industry, but where should cryptocurrency mining and materially similar high-performance-computing services fall in this taxonomic scheme? Where are these data *centers*? Are they on the edge, on the fringe, or somewhere else altogether? The proliferation of data centers (cryptocurrency and otherwise) on the *edge* raises the question of when, exactly, does a data center stop being a *center*, and start being somewhere else? As the need for edge computing infrastructures grows (with, for example, the prospect of autonomous vehicles), the era of the hyperscale data center as the default image for the data center industry may very well fade. The case of cryptocurrency mining illustrates that popular imaginaries of data centers are still hotly contested, and far from settled. These imaginaries are deeply political, and the terrains upon which they are realized are constantly shifting, and have been since the mid-twentieth century. While cryptocurrency mining consumes a massive amount of energy, and many view the practice as wasteful and unnecessary, these codings are also the result of particular political value propositions. Cryptocurrency mining has forced questions about which kinds of data processing are good and useful, and which are not. As a result, crypto, despite itself, has initiated a sort of moral hierarchy of data processing in which industries, communities, and governments can rank specific methods of computing on social and

environmental grounds. The data center has become specified. Will the same hold true as AI infrastructures continue to expand, especially as many cryptocurrency mining firms are actively pivoting to AI and other HPC services? What questions can and should we ask of data centers? What data is necessary in the first place? Who gets to decide? Data centers are articulations of specific relationships, and those relationships are formed and concretized by networks of power and capital. How can they be different? How should they be different? Where should we start?

Where are data centers and why are they there?

Data centers can be found in cities, rural areas, sprawling campuses, closets, or retrofitted buildings and bunkers. Some data centers fade into the background; others demand attention. Some data centers project visions of sustainability or climate neutrality; others embody the aesthetics of power-hungry warehouses. Some data centers sit amid lush greenery and rub up against fresh water; others face the desert heat, arctic cold, or seafloor. Data centers of varying sizes and types can be found all over the world. But increasingly the places data centers are built, especially the hyperscale centers that are owned by the most profitable companies in the world, are not chosen by accident. As critical data center studies scholars have highlighted, data centers are not neutral sites that operate without consequence, nor are they detached from the particular local histories and politics from which they operate.

Put simply, data centers shape and are shaped by their local ecologies (Edwards, 2020; Hogan, 2018; Vonderau, 2017). In other words, the 'where' of the data center matters for many reasons. Not only do data centers rely on the environmental conditions in which they are located to cool servers, but they are also deeply enmeshed with local politics, utility providers, and existing infrastructure (Vonderau, 2019). While Big Tech companies locate data centers to certain locations to increase efficiency and reduce latency of data traffic, there is often a more complex political and economic calculus involved in determining the infrastructural nodes of data center networks.

To determine data center locations, data companies often rely on a set of promises: political promise (i.e., the local, state, and national mechanisms used to attract data companies in the form of tax incentives, water rights, industrial revenue bonds, and so on), climatic promise (i.e., the use of cool air temperatures to decrease computational heat), and infrastructural promise (i.e., the potential for access to fiber optic cable, renewable energy sources, and future growth). Such promises often overlap and are not without conflict. For example, data center providers use discourses of cooler climates as a driver of data infrastructure growth, all the while simultaneously building other data centers in arid climates by leveraging different sets of strategies to justify further development and expansion. Nevertheless, our point here is that there are particular reasons why data centers exist in the places they do; following a data center's emplacement, as many scholars have done, tells us something about the entanglements among digital data and critical categories such as nation, nature, culture, power, and much else.

Operators of hyperscale data centers often make calculated decisions about where to build or expand data infrastructure. Such data centers include those owned and operated by Amazon, Microsoft, Alphabet/Google, and Apple as well as colocation providers such as Equinix, Digital Realty, and China Telecom. Precise location decisions are determined, in part, by the political and economic promises offered by local and state governments. While data center companies balance other factors, strong political will from local and state governments – often in the shape of monetary benefits – is a consistent driver of data center growth.

For example, Facebook's decision to build a series of data centers in Los Lunas, New Mexico happened only after a public bidding contest between Utah and New Mexico. In the end, New

Mexico won the bid over its neighboring state by presenting Facebook with a better incentive package: a 30-year property tax break, annual gross receipt reimbursements, and a long-term guarantee of 4.5 million gallons of water per day (Baca, 2017). However, such decisions to locate data infrastructure to particular places are not frictionless transactions, as local communities, environments, and histories play key roles in brokering (or not) the deals that bring data centers to a geographical area.

The story of Facebook locating its data center to New Mexico over Utah, for instance, involved two states with different political and economic circumstances, not to mention a history of data center extraction in Utah. That history involves the construction of the National Security Agency's (NSA) Utah Data Center, built near Bluffdale, Utah, which has been the subject of public critique and protest for the obscene amount of water and energy extracted from the dry state (Hogan, 2015). Picking up on this historical context, before finalizing the deal with New Mexico, Salt Lake County Mayor Ben McAdams decried the deal with Facebook. As he reported to local news, 'For these 70 or so jobs, we'd be committing to the company water that would be the equivalent of water used by a midsize city. Somebody's going to have to bear the cost of that water' (McKeller and Lockhart, 2016). In contrast, during the time leading up to the deal with New Mexico, local publics found very little, if any, expressed discontent over the terms of the agreement. Local news and state politicians (both Republicans and Democrats) lauded the deal between Facebook and New Mexico as a net 'win' for the state, signaling to constituents that welcoming the data company to the lands and waterways of New Mexico would translate into economic prosperity for the region. Further, New Mexico's elected officials declared that the state was prepared to sustain data infrastructure growth and has the political desire to broker deals with other data companies into the future (Sapin, 2017). As this example of two arid US states courting Facebook makes clear, a local political desire is often necessary for locating data infrastructure to particular places, and it can be years in the making (Burrell, 2020).

In addition, and sometimes in conflict with the political-economic desires mentioned above, the data center industry takes into consideration questions of weather and climate when building new infrastructure in certain regions. Such climatic considerations are crucial for data center operators because, as Jussi Parikka (2015) explains, 'Data demand their ecology, one that is not merely a metaphorical technoecology but demonstrates dependence on the climate, the ground, and the energies circulating in the environment' (24). Given that servers in data centers produce massive amounts of heat because of constant computational work and swarms of electricity rushing into one building, cold climates have been especially attractive for hyperscale data centers.

Many data center scholars have tracked rapid growth of the data industry to cold climates in places such as Sweden, Iceland, and Ireland where access to renewable energy sources adds another dimension of desirability (Brodie, 2020; Johnson, 2019; Vonderau, 2019). These areas have attracted a range of industries reliant on the storage and circulation of data, as evidenced, for example, by (the now failed) Sweden's Node Pole. Although at the time of writing Node Pole has rebranded as a consultancy company, it once positioned itself as a real estate company of sorts that exclusively listed lands and locations for prospective data centers. With a user interface that resembles Zillow or similar real estate platforms, the Node Pole provided prospective data center buyers with statistics such as proximity to nearby cities, rivers, and energy sources. A common selling point here was that data centers can rely on access to cold air as a method to cool data servers. Asta Vonderau (2019b) calls this process 'infrastructuring the air' – or, the 'manipulating and regulating [of] air and data flows' (2). For Vonderau, infrastructuring the air is a geothermal process as well as a cultural and historical one, requiring the 'branding, packaging, measuring, and extracting of [the Nordic air's]

"hot" effects' (2). In other words, 'climate' gets mobilized as both a conditional state ('cool climate') and a business strategy ('a climate for innovation').

As this discursive slippage indicates, considerations of climate are not settled with a thermostat. The 'right' climate for data centers is determined by many conditions including the local political desires already mentioned as well as 'natural', environmental, and risk-factor conditions of place (Brodie, 2020). Typically, finding a data center's 'right' environmental conditions is part of a longer industrial, infrastructural, and often imperial history of a place. As Johnson (2019) notes, data center developers often draw on the political imaginaries of a particular place to construct a perfect or 'natural' fit for new data infrastructure. Johnson's work examining Iceland as a data center hub follows how data companies recapitulate imperial logics that suggest Iceland's cold and desolate 'wilderness' is a 'natural fit' for the emplacement of data (6). These strategic positionings are beneficial to lure new industries to the area, but they also need to be bent when investors question whether Iceland may be too environmentally volatile for long-term growth. Data can live in and be powered by an 'extreme' and 'wild' environment, but such data can also be controlled and managed with precision.

Indeed, Big Tech is increasingly pursuing material and rhetorical modes of controlling or managing localized ecologies. Hogan's (2018) conceptual proposal of 'big data ecologies' engages how Big Tech enters into ecological configurations – often, and increasingly, playing the role of 'custodian and manager of natural resources' (632). Big Tech's model of constructing big data ecologies means that data companies continue to grow their data streams through extractivist practices, all while investing in renewable energy sources, engaging in environmental restoration projects, and projecting images of environmental sustainability. In effect, data companies 'are becoming environmentalists by their own definition, and grabbing at land, water, and power infrastructures to make their case as the industry best suited to manage natural resources, on which Big Tech is dependent (and on which the rest of the economy is also increasingly dependent)' (Hogan, 2018: 632). By performing the role of environmental custodian, the data industry can continue to grow at rapid rates without considering the serious questions behind the why of that growth. In sum, while 'climate' figures into data center locations in a number of ways, Big Tech has practiced its own kind of climate control, adjusting to local conditions by bending different narratives and imaginaries to stage the next phase of expansion.

In addition to political and climatic promises, data centers are built, expanded, and/or retrofitted in specific locations because of infrastructural promises. Data centers often meld into already existing infrastructure such as fiber optic cable lines and renewable energy sources, which themselves are melded into other precursor infrastructures such as telegraph lines and fossil fuel energy pipelines (Hu, 2015; Starosielski, 2015). While the construction of data centers often folds into already existing infrastructures (and, as such, is often touted as an expeditious reason for building new data center sites), the construction of data centers also promises new and more infrastructure: new data centers, new fiber optic cables, new renewable energy sources. Through these promises, data industries and governments justify further development and expansion.

Infrastructures index promise. As Appel, Nikhil Anand, and Akhil Gupta (2018) note, 'new infrastructures are promises made in the present about our future' (27). As many scholars who have studied the strategies used to justify data center placement have argued, data centers are often pitched to local communities and stakeholders through techno-optimist discourses: clean energy, new jobs, new economic diversification. Yet, as Appel, Anand, and Gupta also note, 'insofar as [infrastructures] are so often incomplete – of materials not yet fully moving to deliver their potential – they appear as ruins of a promise' (27). In the context of data center infrastructure, we are already witnessing the limits of the promises made to justify the industry and the ruins they might

produce. Big Tech firms are now setting their sights on different promises for the future of data growth, which include, for example, new storage formats and technologies such as synthetic DNA (Hogan and Verhoeven, 2020) and undersea data centers, as well as further integration of energy and cloud infrastructures (Velkova, 2021).

Future trajectories

Based on what we have identified in this article, we imagine that future directions for Critical Data Center Studies will involve continuing to track the ever-evolving concept of 'the data center', paying more attention to questions of labor in the industry (especially as related to changing planetary conditions), and to growing concerns around the materiality of 'artificial intelligence' ('AI') and other future iterations of data storage and computation. With the recent turn to 'AI' by all major Big Tech companies, the infrastructure to support data has also changed. 'AI' requires more power, more water, more mineral and material support. While some components of 'AI' might render tasks in the data center more efficient and cut emissions – by optimizing energy consumption, predicting equipment failures, and automating maintenance tasks – the so-called efficiencies of the data centers themselves are a foil against addressing the very real, very urgent concerns that computational-thinking and -doing exacerbate. As such, we propose these three future trajectories specifically because they address both changing typologies and the changing field of research surrounding Big Tech future imaginaries, the internet, 'AI' and/as 'The Cloud'.

As we've shown, Big Tech is an aggregate of companies of vast material infrastructure working to accumulate significant pools of data for industries and scientific endeavors like policing, surveillance, forensics, genomics, health, finance, banking, trading, the military, ecology, space research, and so on. In 2022-23, it has been made very clear that much user-generated data has been used to train AI for what is being called 'generative AI' which essentially works as a massive scale auto-complete system, or as large-scale computational statistics. This is enabled by both political and material infrastructures, and allocates a tremendous amount of power to the data center industry. The data center industry is often disguised as, or combined with, other services – like OpenAI, Google search or Amazon retail – but the power of these companies is in the processing and storage of data – The Cloud. As recently noted by Mirrlees (2021), Big Tech's power is both structural and relational – meaning power is about ownership and influence on regulation as well as on governance and compliance by their users.[1] From this, we've demonstrated that the data center itself is, in some ways, irrelevant to Critical Data Center Studies, in the sense that the physical 'center' is a mere object-concept that enables scrutiny of the modes and modalities by which Big Tech impacts and increasingly shapes society and alters planetary conditions. What constitutes a data center, imagined as a central repository for big data, and the significance of it as a material infrastructure, is likely to matter less in the future, as the data center changes shape and operational modalities. In other words, what we consider a data center today may very well look and feel very different in the not-too-distant future – with the advent of quantum computing, biocomputation, and synthetic DNA data storage, as examples. This is in part why the continued documentation of these data center sites is so important, so that their ensuing logics and politics can't evade us. By tracking the changing nature of the data center itself, scholars, artists and activists are better positioned to challenge the industry and make recommendations for a more just and equitable society enabled by globally networked infrastructure.

It is very difficult to draw firm and clear boundaries between Big Tech media objects – between a data center, investments in the logics of the internet, and their global impacts. So while we've attempted to provide a typology of data centers in this article, in part with the hope of demonstrating

their shifting nature, we hope to have also shown that Big Tech is deeply imbricated in creating its image, away from cloud services and into human services. This is where attention should be placed as the data center itself morphs conceptually and materially – with each new promise, each new trend: bitcoin, crypto, NFTs, 'AI', and so on. We need to key our eye on promises made by Big Tech, knowing these are enabled by their unparalleled data processing power and the concentration of the power in and by Big Tech. This does not mean that big data amounts to truth; quite the opposite, it means that big data is deployed as Truth by Big Tech (and especially with industrial AI) without much challenge because of its inherent scope and scale. The making of Critical Data Center Studies obviously centers the data center, but as we hope we've demonstrated in this article, the 'data center' is simply a concept that helps scholars, artists and activists to locate the site of their arguments against Big Tech takeovers.

Conclusion

Our article has surveyed the emergence of Critical Data Center Studies as an interdisciplinary field focused on interrogating the politics and materialities of internet infrastructure. By reviewing key questions, concepts, and research trajectories, we aimed to synthesize the diverse scholarly conversations that now orient around the data center as a site of critical inquiry. The literature shows data centers take shape through an array of environmental, social, economic, and political forces that exceed purely technical logics. Tensions and conflicts often underlie the emplacement of data centers within specific local contexts; tracing these conflicts and contexts is crucial for denaturalizing data infrastructures and igniting new sociotechnical imaginaries.

Several important themes and debates run throughout the field of Critical Data Center Studies. One major theme centers on the environmental impacts of data centers, especially their massive energy and water demands. As cloud computing expands, researchers are increasingly asking how to balance so-called efficiency improvements with reductions in natural resource extraction. Critical scholars also highlight the broader material effects of data center supply chains, waste, and emissions. These planetary impacts raise questions of environmental justice, as marginalized communities often shoulder the burdens of extraction and pollution.

Another significant theme that we tried to cover is the relationship between data centers and public infrastructure. Scholars have pointed to the ways private cloud companies benefit from public subsidies, tax incentives, land deals, access to utilities, and more. This prompts examinations of how public funds support private data center expansion, and what obligations companies incur in exchange.

Researchers also explore labor practices and conditions in the data center industry, drawing connections between data infrastructures and forms of precarious or invisible work (often as maintenance work). For this, we propose that more interdisciplinary observational and ethnographic research be conducted with people working in the industry, including policy makers, politicians, and those working in places where the data center was offered as a promise of economic revival. This includes more interviews and conversations with a range of folks on the periphery of the industry: from small town service workers during building booms, data center and undersea cable repair and maintenance workers, activists fighting the use of coal to power data centers,[2] to those resisting the emplacement of data centers in 'the north', and so on. After a careful analysis of the field, we urge future researchers to seriously consider ethnographic work (over the fetishization of the data center as a site) as the most essential methodological intervention in expanding the frame of who has counted and who has been left out of the current collective scholarly understanding of the data center, Big Tech, and the internet more broadly. Ethnographic work brings into relief the truly global

and unequal impacts of the internet, and might invite scholars to think of themselves more as activists affecting change in the field than as documentarians of the problems.

One of the key components of marketing the cloud is in the industry's promise to rebuild economies, to be built in the ruins of now defunct industries (Jacobson and Hogan, 2019; Johnson, 2019; Pickren, 2017; Vonderau, 2019). As Mayer (2019) has argued, there's an aura specific to working with Big Tech that pulls people in despite rarely financially benefiting them, or the small towns that are supposedly being revived. There are also different tiers of jobs in the industry, core and peripheral, which ensure more or less stability in the long-term. As we show, more ethnographic work needs to be done on data center labor to better understand what workers face in this industry. More work also needs to follow the lead of Greene (2022) who asks us to consider who owns the internet, as global networks, and who are its landlords. And as Steven Monserrate Gonzalez (2023) also demonstrates, we need more focused attention paid to the cloud by way of environmental ethnography.

Ultimately, Critical Data Center Studies puts core issues of power, inequality, and justice at the heart of research into digital infrastructure. The field strongly counters techno-utopian narratives of an immaterial, placeless cloud. Instead, scholars foreground how particular interests, visions, and relationships become concretized in data centers. This political-economic analysis combines with attention to the cultural imaginaries and affective dimensions of data centers. Ongoing work must continue expanding the range of voices represented in Critical Data Center Studies. By spotlighting more diverse experiences and subjectivities related to data centers, we can reshape the geography and ontology of critical research.

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Notes

1. https://environmentalmedialab.com/heliotrope/getting-at-gafams-power-in-society-a-structural-relational-framework.
2. https://www.reuters.com/article/us-apple-ireland-idUSKBN1CH1EC; https://thenextweb.com/news/greenpeace-activists-scale-apple-offices-in-ireland-in-protest-over-coal-powered-datacenters.

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