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Mapping the clouds: the matter of data centers

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ABSTRACT

The social spatial geographies of telecommunications and their infrastructures have long interested scholars in the social sciences, and in urban geography specifically. This paper focuses on data centers. Much effort has been placed in preserving the notion that data centers are 'clouds', a terminology that obfuscates the real human geographies of cyberplaces. In this map-making exercise, we visualize the sociopolitical human geographies of data centers, and provoke the reader to consider the impacts that data centers have on residents and their environments. The maps shown in this paper suggest four trends. First, hyperscale data center owners are building near large waterways, signifying a shift in location preferences. Second, data centers stress local administrations, financing, and availability of upstream resources, as hyperscale data centers step up their input needs. Third, data center development is state-led. Fourth the competition for data center industries unfolds across a multi-level governance context.

1. Introduction – obscured by clouds

The material, socioeconomic and political geographies of telecommunication infrastructures, roads, railways, water and sewage systems are thoroughly documented, including a number of innovative mapping methods in this journal such as Lehrman (2018) or Molinero-Parejo et al. (2021). Thousands of maps of cyberspace, too, have been made, as the social spatial and human geographies of telecommunications and their infrastructures has long fascinated scholars in the social sciences (Dodge & Kitchin, 2001; Graham & Marvin, 1996; Kitchin, 1998; Malecki, 2002; Wheeler et al., 2000). This literature has developed a variety of conceptual approaches to understanding the complex social spatial geographies of new technologies and respective 'backbone' infrastructures of information and communication. In this entry – elaborating on (Bast et al., 2022) – we focus on mapping data centers (DCs) as a particular new kind of digital infrastructure.

Scholastically, the study of DCs is still largely confined to the fields of engineering and computer science where rigorous debates are unfolding around new technologies – such as chip development, processing power, or innovations in energy efficiency (Fleischer, 2020) – with fewer disparate observations and reflections across the social sciences (Atkins, 2021; Brodie & Velkova, 2021; Jacobson & Hogan, 2021; Maguire & Winthereik, 2021; Patchell & Hayter,

2021; Pickren, 2021; Zuboff, 2019). While the human geographies of DCs remain largely unexplored, large digital corporations seem keen on maintaining the opacity. Their non-transparent operations and political maneuverings have already been critiqued elsewhere (Bast et al., 2022; Carr & Hesse, 2020a, 2020b; Flynn & Valverde, 2019; Goodman & Powles, 2019) and the notion of the 'cloud' is in line with this practice of obscurity.

There are many different kinds of cloud computing such as virtualization, grid computing, artificial intelligence, platform services, blockchain and more. The 'cloud', however, is a terminology that distracts from the concrete, material corporealities of DCs, and fogs up, obfuscates, overshadows the actual existence of the places of 'cyberplaces' (Devriendt et al., 2008; Malecki, 2002); that is, the places where server farms are located and data processing occurs. Cyberplace:

> consists of all the wires that make up the networks that are embedded into structures; these wires are […] difficult to chart. [Yet, all] networks, including wireless networks, have a built infrastructure that relies on antennas and connection with conventional telephone switches. (Malecki, 2002, p. 401)

DCs form part of the 'real-world spatial fixity' (Kitchin, 1998), the 'meatspace' (Stephenson, 1996) of the internet, which through the 'power of wires […] changes the geometry of the world of commerce

and politics and ideas that we live in,' (Stephenson, 1996).

2. Maps as concrete manifestations

Wood (1992) wrote that the 'power of maps' lies in a map's selectivity; that is, the highlighting of certain features while suppressing others: Ultimately, 'a map is imbued with the values and judgements of the people who construct it' (Dodge & Kitchin, 2001, p. 3). Reinforcing the imagery of the 'cloud' is thus a practice of power, negating the actual geographies of 'social space', (Lefebvre, 1991, p. 26). This paper maps the material geographies of DCs as new urban infrastructures. Following Vélez and Solórzano (2018, p. 160): 'maps and map-making […] illuminate how the spaces that define our lives are not arbitrary, but rather concrete manifestations of the complexity of social life.'

In this cartographic exercise, we visualize the socio-political and human geographies of DCs, engaging map-making as a method of exploration (See Main Map). This work departs from engineering and computer sciences, where 'mapping' is a tool for working out problems associated with construction, organization and optimization of DCs, or cataloging of land resources for future DCs (e.g. Zhong et al., 2009). We contribute instead to the scholarly body of literature that aims to understand the human geographical and urban societal implications of DCs, addressing ramifications on labor, real estate, geographies of policy and investment, and the competition for resources that DCs depend on (Atkins, 2021; Bast et al., 2022; Brodie & Velkova, 2021; Jacobson & Hogan, 2021; Maguire & Winthereik, 2021; Molenaar, 2016; Patchell & Hayter, 2021; Pickren, 2021; Van der Giessen, 2017; Zuboff, 2019). The maps shown in this paper represent the conceived spaces (Lefebvre, 1991, p. 38) of DCs, as one empirical leaf (Diener et al., 2006), in the '*mille feuille* […] of uneven spatial development […] composed of complex, messy articulations among multiple patterns, layers, contours, lines, folds, points, clusters, and edges.' (Brenner, 2019, p. 51).

3. Methods and maps

As part of a wider project funded by the Luxembourg National Research Fund entitled, 'Digital urban development – How large digital corporations shape the field of urban governance (DIGI-GOV)' (Carr, 2021) that examines the impact of Amazon or Google on urban development, the specific task at hand here was to find out where DCs are, explore their relationship to territory and governance, and get a sense of the scale of resource consumption. In previous work, we examined this question in the Washington Metropolitan Area (Bast et al., 2022), uncovering the significant

gaps in the public record, especially in regards to the consumption needs of Amazon.com. The Seattle area, The Grand Duchy of Luxembourg, and The Netherlands were three further urban regions that DIGI-GOV focuses on because they host, or want to host, hyperscale businesses. Seattle is a metropolitan region with a population of just over 4 million, functionally integrated across several counties of Washington State, and encompassing hundreds of municipalities. Luxembourg is also a metropolitan region with a population of almost 650,000, spanning over a hundred autonomous municipalities governed by a central state. The Duchy is further functionally integrated with neighboring countries in what is known as the Greater Region that has a total population of over 11.6 million (Les offices statistiques de la Grande Région, 2021). Amsterdam is the capital of The Netherlands, with a population of c.a. 2.5 million across the metropolitan region (Gemeente Amsterdam, 2021).

The maps were designed to communicate issues well known in engineering and computer sciences about resource consumption to audiences in human geography. Contextual maps are provided, locating (a) the Grand Duchy of Luxembourg in the Greater Region, (b) Seattle and the functionally related satellite municipality of Quincy in the State of Washington, and (c) Amsterdam in The Netherlands on the northwest coast of Europe. Energy consumption of each DC is drawn to scale to expose the pressures on resources that DCs exert. A relief of city buildings helps the viewer recall that these metropolitan areas are spaces where people live, work and compete with DCs for resources.

Data were scraped from online sources such as baxtel.com, datacenters.com or datacenterhawk.com, whose main function is to provide up-to-date news, market analysis, and information for and about actors and institutions in the field such as data processing providers, IT professionals, real estate agents, business consulting firms and investors. These resources tabulate the names of companies, their locations, the various kinds of facilities at work, and the services offered. These are regularly used by leading civil engineers in the field (Siddik et al., 2021). Further data were also gleaned from the websites of DC operators themselves. This data were much less consistent, as there are few (if any) regulations determining what a company must reveal.

There are thus limitations in the data sets, and by extension, the maps. First, there is the methodological problem observed by early cartographers of cyberplaces that, 'one must be aware of the dangers of taking data collected and maintained for one purpose and then using it for another, possibly unforeseen and unrelated, application,' (Dodge & Shiode, 2000, p. 46). Second, while the maps aim to inventory DCs in the

respective city regions, the rapidly changing industry and fragmentary character of available data render the maps more tentative and investigative. The various sources provide different kinds of data, while DC websites are inconsistent with what they divulge. Holes in the data are also represented on the map. These indicate not only a research deficit, but also a dearth in the public record concerning what these digital infrastructures are doing and demanding.

Data were processed using MS Excel and maps were drawn with ArcMap 10.3.1 and further processed with AutoCAD and Adobe InDesign. Individual maps are provided in Figures 1–4. A large supplementary map in format A0 is also available for download. Table 1 overviews the eight largest DCs detected.

4. Conclusion – data centers matter

The maps shown here reveal spatial patterns of DCs, but only barely scratch the surface of this human geography. Certainly, far more work – and better data – is needed to conceive its full extent: Future explorative maps might show, for example, other kinds of data such as names of institutions or more technical components of the infrastructure such as IXPs. Still, certain trends can be detected as DCs are

not randomly dispersed across space. Most striking is that the geography of the current-day internet is still much as it was, concentrated in metropolitan areas where the demand is high and where the path-dependent cycle of technological development unfolds. Greenstein's (2018) referred to this as the 'technology tel':

> Technology tels grow due to three economic factors: infrastructure is built in locations where the most users create the most demand, the presence of a prior generation lowers the cost of installing the next, and technical factors raise the productivity of collocating two distinct pieces of equipment. These factors reinforce one another, keeping equipment in the same location. (Greenstein, 2018, p. 78)

This is evident today as DCs require access to electrical grids and telecommunication infrastructure (Alizadeh & Iveson, 2020; Greenstein, 2018), confirming the 'long history of cities and communications technologies' (Rutherford, 2011, p. 21). The geographies of DCs specifically, however, are nuanced.

First, the maps show the shift in location towards sources of water. Much attention has been given lately to the energy and water consumption of DCs. The cooling of hyperscale DCs is a particular problem (Fleischer, 2020; Siddik et al., 2021). While
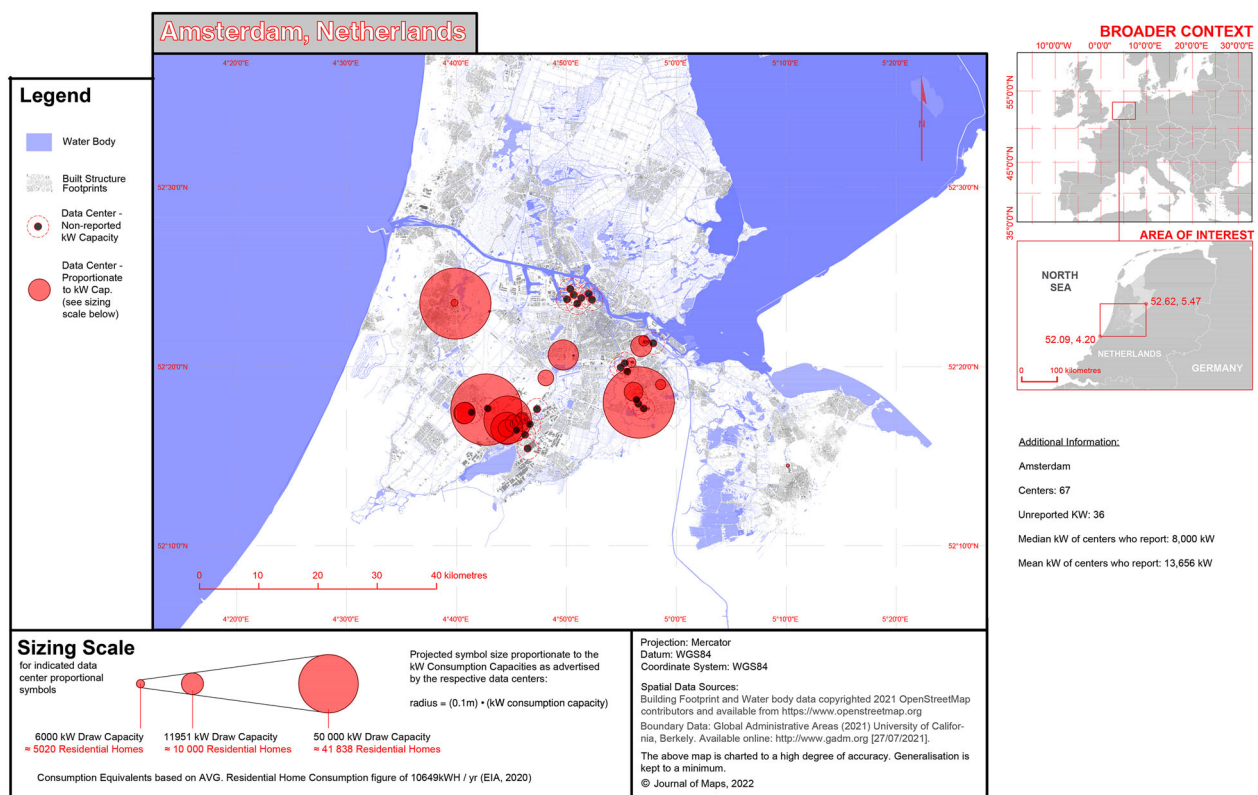

Figure 1. Data centers in Amsterdam. A map of the city of Amsterdam with 67 opaque circles plotted over the underlying city. Each circle corresponds to the location of an Amsterdam data center. Red opaque circles vary in size to reflect the kilowattage capacity of the data center in that location. Their radii are based on the following formula: (0.1 m)*(kW Consumption Capacity). Amsterdam has several large circles, some representing excess of 50,000 kW, the equivalent of over. Black opaque circles represent data centers whose kW capacities were not reported and could not be found. Amsterdam has approximately as many black circles as red.
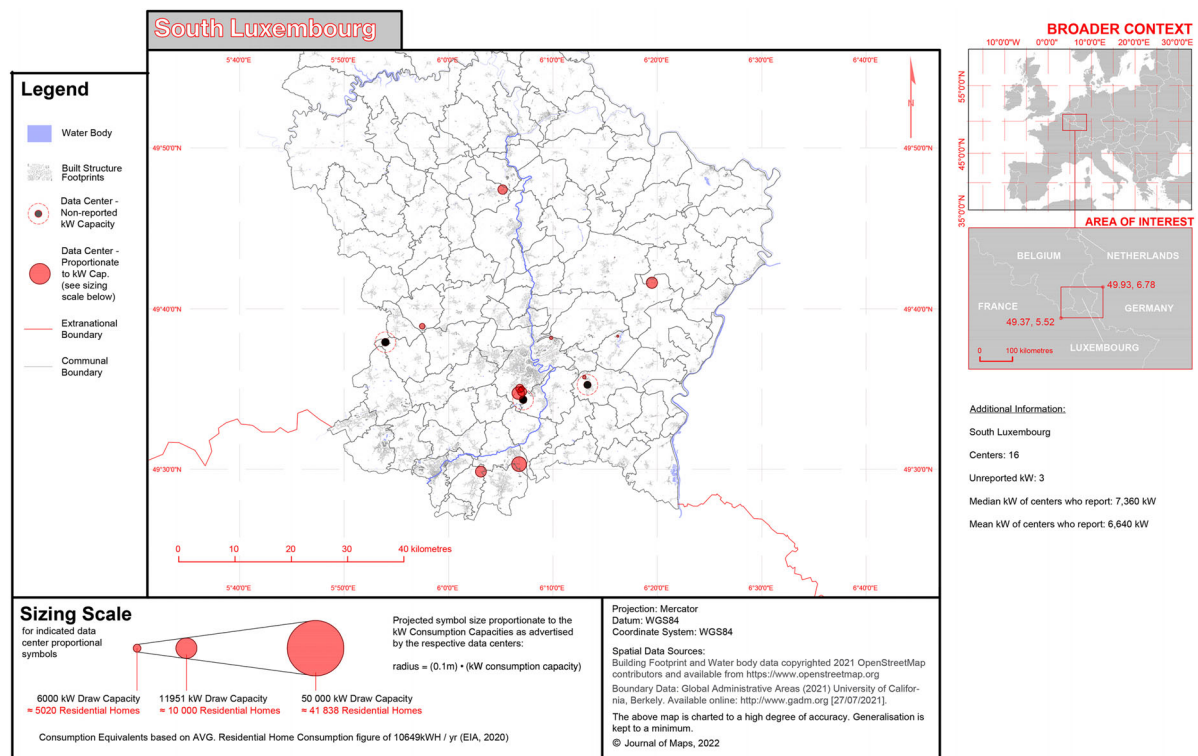
Figure 2. Data centers in Luxembourg. A map of Luxembourg with 13 opaque circles plotted over the underlying country. Each circle corresponds to the location of a Luxembourg data center. Red opaque circles vary in size to reflect the kilowattage capacity of the data center in that location. Their radii are based on the following formula: (0.1 m)*(kW Consumption Capacity). Luxembourg's data centers have small to medium sized radii, usually boasting a capacity below or near 10,000 kW, the equivalent of less than 10,000 residential homes based on 2020 figures from the EIA. Black opaque circles represent data centers whose kW capacities were not reported and could not be.

Figure 3. Data centers in Seattle. A map of Seattle with 46 opaque circles plotted over the underlying country. Each circle corresponds to the location of a Seattle data center. Red opaque circles vary in size to reflect the kilowattage capacity of the data center in that location. Their radii are based on the following formula: (0.1 m)*(kW Consumption Capacity). Seattle's data centers have a diverse range of radii, some boasting capacities near 50,000 kW, the equivalence of 40,000 residential homes based on 2020 figures from the EIA. Black opaque circles represent data centers whose kW capacities were not reported and could not be found. Seattle's map features very few black circles.
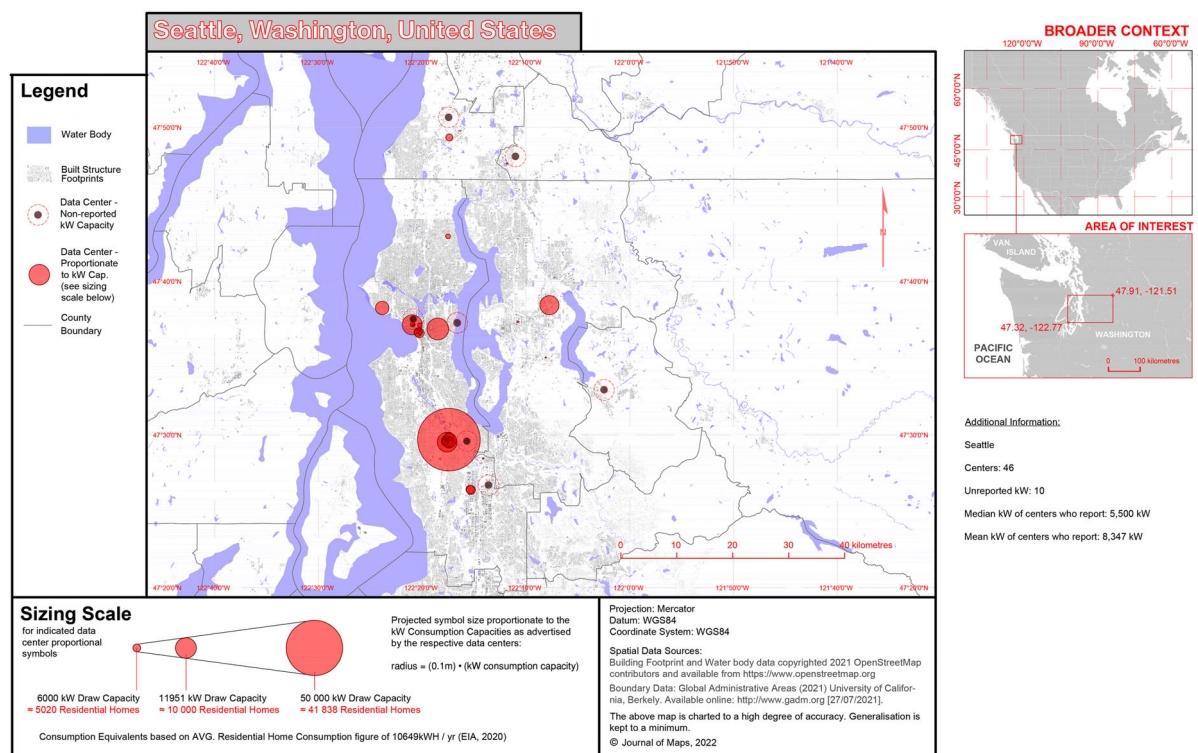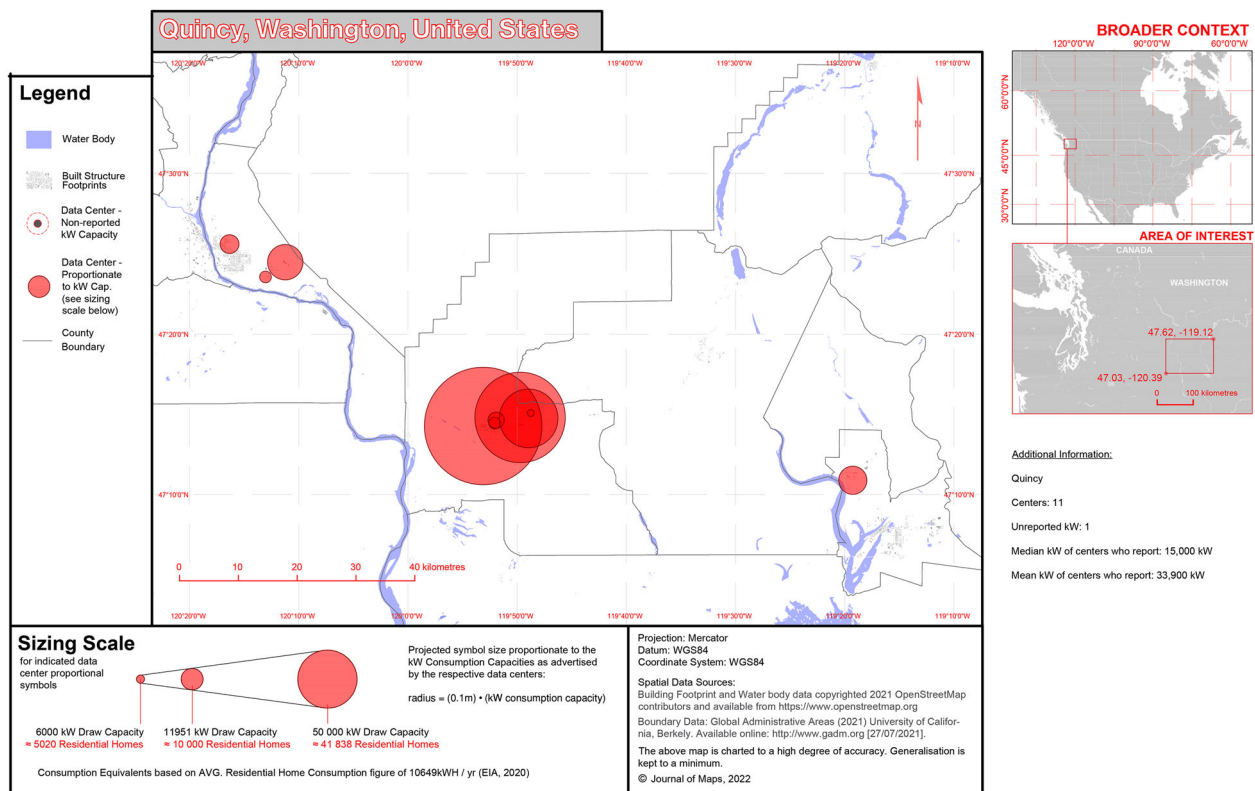
Figure 4. Data centers in Quincy. A map of Quincy, Washington with 11 opaque circles plotted over the underlying country. Each circle corresponds to the location of a data center. Red opaque circles vary in size to reflect the kilowattage capacity of the data center in that location. Their radii are based on the following formula: (0.1 m)*(kW Consumption Capacity). Quincy's data centers have a diverse range of radii, some boasting capacities as high as 100,000 kW, the equivalence of 80,000 residential homes based on 2020 figures from the EIA. Per the USA Census Bureau, Quincy Washington in 2019 had a population of nearly 8,000 people. Black opaque circles represent data centers whose kW capacities were not reported and could not be found. Quincy's data sheet only had one center with an unreported kW capacity.

innovations in building architecture (e.g. ventilation) have improved operating efficiencies, water-cooling is the most common method and will remain so until new technologies are invented that respond to increasing demand and changing technologies (Fleischer, 2020). For this reason, many hyperscale DCs are built on or near rivers. This, which confirms Bast et al.'s (2022) work, is easily seen in the map of Washington State. It is less obvious in the map of Luxembourg, perhaps due to a confusion about definition, but also to problems in the availability of information. Currently, the European Data Hub qualifies as a hyperscale in terms of square footage, but not in terms of services. Also, while Google plans to build a hyperscale DC along a major water conduit in Luxembourg, it is not mapped because it does not exist yet, mired currently in local politics (Mouvement Écologique, 2022).

Second, the maps show the scale of energy consumption, the impact on society and how this is spatially distributed. Indeed, there have been significant achievements in regards to energy efficiency:

Though the amount of data center computing workloads has increased nearly 550% between 2010 and 2018, data center electricity consumption has only risen by 6% due to dramatic improvements in energy efficiency and storage-drive density. (Siddik et al., 2021, p. 1)

It is important however to note that, 'electricity use [is not] necessarily indicative of the workload demand for data center services'. The maps thus show the stress that DCs pose on local resources. Most notable are the largest hyperscale DCs (Table 1). Hyperscale DCs represent a new generation of DCs that consume enormous quantities of power, irrespective of their processing power efficiency.

Third, DCs locate themselves following local policy decisions aimed at capitalizing on digital industries and their respective markets. In this respect, one can speak of state-led digitalization, as scholars in neighboring urban studies disciplines have done (Hochstenbach, 2017). Governing officials in places like Luxembourg and Quincy target institutions active in the digital economy and attempt to attract and maintain them as a source of revenue (City of Quincy, 2016; Digital Luxembourg, 2022; Molenaar, 2016). In Figures 1–4, one can see that DCs concentrate inside the boundaries of certain jurisdictions, namely those likely with the sovereignty to develop and govern a competitive niche economy for global flows (Hesse,

Table 1. Overview of the largest data centers found in the Amsterdam and Seattle areas.[a]

Name	Performive AMS1 (Equinix)	Iron Mountain Amsterdam	PhoenixNAP Amsterdam	E-shelter Amsterdam Data Center	Microsoft Quincy MWH (Microsoft Oxford)	Yahoo Oath Quincy	Sabey Intergate Quincy	Sabey Intergate East
City	Amsterdam				Quincy			Seattle Area
Megawatts		60	60	40		60		
Surface (m²)		40,000	n.a	16,000	186,000[b]		39,000	
Year	n.a	n.a	n.a	2019	2014–2018[c]	2007–2018[d]	2011	2004[e]
Number of servers	n.a.	n.a.	n.a.	n.a.	ca. 500000[d]	n.a	n.a.	n.a.
Hyperscale	yes	yes	no	yes	yes	yes	no	no
Services	Cloud; Colocation; Backup; Disaster Recovery; High Security	Cloud; Colocation: High Security; Office Space	Cloud; Colocation; Hardware Leasing; Disaster Recovery High Security	Cloud; Colocation; High Security	Cloud; High Security	Cloud; High Security	Colocation; High Security; Office Space	Colocation; High Security; Office Space

[a]All data derived from company and industry websites accessed August 26, 2021 (performive.com; ironmountain.com; phoenixnap.com; www.e-shelter.de; luxconnect.lu; sabeydatacenters.com; datacenters.com, baxtel.com) except where further noted.
[b]CNET (2021) https://www.youtube.com/watch?v=80aK2_iwMOs.
[c]The State of Washington conducted an ecological review in 2014 (https://apps.ecology.wa.gov/publications/SummaryPages/1402014.html) and approved a second major expansion in 2018, doubling the infrastructure (https://ecology.wa.gov/DOE/files/74/7444566f-931f-4642-a864-5d3216494c09.pdf).
[d]The Yahoo-Oath DC first came into operation in 2007 and was revamped in 2011, 2014 and 2018 (State of Washington Department of Ecology (2020) https://apps.ecology.wa.gov/publications/documents/2002019.pdf).
[e]The City of Tukwila rezoned the Low Density Residential property to Manufacturing Industrial Light in 2004 (records.tukwilawa.gov/WebLink/DocView.aspx?id=10035&searchid=66f3700c-607c-43fa-861e-f77221f2b71a&dbid=1).

2016). This is seen in the maps of Luxembourg that reflect recent policy decisions in the Duchy. It is also seen in the City of Quincy (a satellite village of Seattle) that also has a palate of policy decisions encouraging DCs, maximizing its proximity to both a river and offering tax advantages to clients (City of Quincy, 2016).

Fourth, cities and nations can compete for DCs that will anchor capital investments and tax revenues (Molenaar, 2016). In this respect, the maps illustrate how these authorities are distributed across multi-level governance structures (Hooghe & Marks, 2003; Affolderbach & Carr, 2016). The sovereign ability to develop a local economy and reap respective revenues lays at the municipal level in the State of Washington (City of Quincy, 2016) as seen in the maps. In Luxembourg, by contrast, this authority lays at the level of the central state. In the case of Luxembourg too, this has caused difficulties in generating public acceptance of Google's upcoming data center, because decisions of national interest lay behind closed doors (Mouvement Écologique, 2022).

Software

Data were sorted using MS Excel. The maps were drawn with ArcMap 10.3.1, then further processed with AutoCAD and Adobe InDesign.

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Data availability statement

Data were derived from baxtel.com, datacenters.com and datacenterhawk.com which provide data in the public domain. Neither fee nor a registration is required to access this data.

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