Unraveling the “Digital Gateway to Europe”: Examining the spatial and environmental impacts of data centers and their governance

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Abstract:

Data centers, which power the digital economy and advanced digital services, and serve as the “backbone” of smart cities, have an expanding spatial and environmental footprint. As the capabilities of the internet and advanced technology (such as AI and VR) become more prevalent, the data center industry is expected to grow. Despite the opportunities afforded by digital infrastructure, data centers are reported to also have notable spatial and environmental impacts —including significant energy usage. These consequences are apparent in Amsterdam which has become a leading European hub for colocation data centers. In the social sciences, notably in the field of smart cities and critical data studies, there has been limited empirical research on data centers. Existing research has examined the social and the environmental implications of data centers but there has been less examination of the impact these facilities have on urban infrastructure and how they are governed. Using Amsterdam as a case study, this research uses a sociotechnical analysis of networked infrastructure and examination of smart urbanization as well as cloud geographies and ecologies to explore the impacts of data centers on spatial planning and energy grids and how they are governed. The research concludes that data centers have benefitted from the reliability of energy grid and influenced the local governance of energy grid development. However, there continues to be challenges in governing a nontransparent but rapidly evolving industry.

Key words:

Data centers; cloud geographies & ecologies; energy grid; energy usage; smart cities; spatial planning; digital infrastructure; residual heat; governance; transparency; Amsterdam

Introduction

In 1988, at Amsterdam’s Science Park, home to the national research institute for mathematics and computer science (CWI), the Netherlands became the first European country to be connected to the Internet (Centrum Wiskunde & Informatica, n.d.). Soon after, in 1994, the Amsterdam Internet Exchange (AMS-IX) opened, propelling Amsterdam into a small but growing network of cross- continental internet connections. In 1998, a Dutch company called Interxion, founded the a colocation data center in the Netherlands (van de Geer, 2019). Less than 30 years later, by 2019, the company operated thirteen data centers spread across two campuses in Amsterdam Science Park and Schiphol Rijk with dozens more across European metro areas. In 2019, Interxion was purchased for $8.4 billion (USD) through a corporate merger (Judge, 2019b). Today, the company operates nearly 300 colocation data centers around the world. Interxion, while one of the largest in the market, is one of many data centers that have had similar trajectories and expanded their spatial footprint and energy demands in Amsterdam and in metro areas around the world. As the exponential growth of data continues, metropolitan areas have become important nodes for data centers to quickly (within milliseconds or even microseconds) communicate data. Nevertheless, the fast-paced expansion have put strains on urban space, energy grids and local governance. In Amsterdam, municipal, provincial leaders, utility stakeholders and public-private partnerships are navigating how to both govern and accommodate the internet's complex, burgeoning infrastructure.

Sometimes referred to as "the central nervous system of the 21st century," (Whitehead et al., 2014) data centers are the physical infrastructures of cloud technology and are the core of internet provisions including data processing, storage and dissemination (Diguet & Lopez, 2019). Data centers provide many of the services that internet users now rely on, such as e-commerce purchases, online banking, movie or music streaming, gaming, social network usage and online storage of documents, photos and other digital assets (Holt & Vonderau, 2015, p. 5). Furthermore, the major and sudden shift to remote work during the COVID-19 pandemic was largely feasible through cloud services. Data centers are enabling advanced digitalization including 5G-rollout, Artificial Intelligence (AI) and Internet of Things (IoT) (Maida, 2021; White, 2020). They serve as the "backbone" (Lam et al., 2019) of smart cities by processing, and communicating "real-time data" (Lam et al., 2019) which have been promoted to provide sustainable or efficient solutions to manage urban infrastructure, climate, mobility, and waste. In addition to serving as a mediator of data, the industry is receiving recognition for its large-scale investment in renewable energy and their potential ability to provide residual heat to nearby commercial, residential facilities. Despite the opportunities afforded by digitalization, there are also notable environmental and spatial impacts of these large digital artifacts including energy consumption, water use, and large-scale land-use (Diguet & Lopez, 2019).

In urban social science research there has been limited examination of the infrastructure and artifacts needed to support widescale digitalization and data processing (Diguet & Lopez, 2019). Rather scholarship has focused on the social and political implications of urban tech-enabled smart cities (Pickren, 2018). On the other hand, though there is growing research on the geographies and ecologies of data centers (Amoore, 2018; Furlong, 2021; Holt & Vonderau, 2015; Jacobson & Hogan, 2019; Johnson, 2019; Kinsley, 2014; Velkova, 2016) and their environmental impacts (Brodie, 2020; Diguet & Lopez, 2019; Hogan, 2015; Koronen et al., 2020; Mytton, 2021; Velkova, 2016, 2021) there is limited empirical research on the urban environmental and spatial impacts of data centers (specifically colocation) in metropolitan regions and how these digital infrastructures are being governed. As the colocation data center industry grows and evolves rapidly, it is necessary to examine its spatial and environmental impact on urban and peri-urban spaces and how they are governed.

Amsterdam offers a useful case to examine the interrelated relationships of digital infrastructure, energy grids and obstacles for urban energy and land-use governance. This is for a few reasons. Amsterdam has been recognized as a leader in smart city initiatives and digital governance (Mills et al., 2021; Mora & Bolici, 2017). The city has ongoing efforts to enhance digital programming (Gemeente Amsterdam, n.d.). Additionally, Amsterdam's historical and current investment in digital infrastructure (Gemeente Amsterdam, n.d.) has made it an ideal location for the data center industry as it offers many of their core needs: including proximity to internet cables and telecommunication infrastructure, proximity to dense markets and customers which ensures rapid communication and reduced latency (*Dutch Data Centres Continue to Flourish, with Amsterdam Leading the Way.*, 2018; Gementee Amsterdam, 2020). In Amsterdam, data centers can also access reliable, affordable and renewable electricity—which is an important locational factor for many data center providers and their sustainability ambitions (Dutch Data Center Association, 2020). Nearly 30 colocation/multi-tenant data centers are in the municipality of Amsterdam. There are approximately 23 in Haarlemmermeer (Boele, 2020), which neighbors the municipality of Amsterdam and has experienced a similar influx of data centers. Despite the potential opportunities available in Amsterdam region, there are governance concerns and debates about how to accommodate this industry, specifically the intense pressure on local energy grids. The significant growth of the data center market has led to pressures on energy and space and triggered policy interventions aimed at curtailing uninhibited data center development.

In Amsterdam, the increase in data centers had become contentious (Judge, 2019a). In June 2019, the Amsterdam municipality, and the adjacent Haarlemmermeer municipality**,** announced a moratorium on data center construction citing concerns of uncontrolled growth, high demands of energy consumption, and spatial limitations in the region. According to city councilmembers, the moratorium would provide time for policymakers to develop a more comprehensive roadmap for future data center planning (Gementee Amsterdam, 2019). In 2020, both municipalities published policies that called for more sustainable planning (Gementee Amsterdam, 2019). In the Amsterdam municipality, the regulations limited data center construction to four business parks with remaining space for clustering, required certain aesthetic qualities and mixed-use functionality. Additionally, the policy called for regulations on energy grid connections and obligations for data center operators to provide free access to residual heat (Moss, 2020). While the industry's growth is expected to accelerate in the Amsterdam region (Dutch Data Center Association, 2020; Judge, 2019a), there are now more formal policies aimed at governing their development.

While Amsterdam continues to promote its role as a leader in smart city initiatives and as a "digital gateway" to Europe, the city wrestles with how to manage the large digital infrastructures as the key infrastructural backbones of such ambition. The main aim of this paper is to explore the spatialities and ecologies of data infrastructures. This is done by investigating the challenges in the provisions of urban space and urban electricity, the perceptions and opportunities of data centers as residual heat providers and the overall challenges of governance for this complex ecosystem.

This article first, aims to understand spatial and environmental considerations of data center planning in the Metropolitan Region of Amsterdam. The next is to examine how data centers are spatially and environmentally governed and lastly to explore whether and how governments and stakeholders address the spatial and environmental considerations of data centers as the infrastructural backbone of smart cities.

Sociotechnical Perspectives on Urban Data Infrastructures

Data centers are having notable impacts on the political, economic, environmental, and infrastructural development of modern-day cities. The complex role of data centers as a major energy consumer, a potential heat energy provider and as the "backbone" of smart city applications, can be analyzed through a sociotechnical, networked infrastructure approach.

Networked infrastructure was long seen as a method to improve urban spaces and the lives of urban residents through public or government investment. However, political changes starting in the late 1960s- 1990s led to "unbundling" of infrastructure or "splintering urbanism" (Graham & Marvin, 2001) where infrastructure provisions "shifted from relatively coherent and equitable systems – based on the idea that infrastructures are economic 'natural monopolies' – to a complexity of fragmented institutional providers" (Monstadt & Coutard, 2019, p. 2196). Some of the shifts in the infrastructure services have led to the "emergence of new and independent infrastructure subsectors"(Monstadt & Coutard, 2019, p. 2196) such as renewable energy providers and ICT companies seeking access to the "utility and urban service market" (Monstadt & Coutard, 2019, p. 2196).

The emergence of digital infrastructures has become increasingly relevant for urban development and has witnessed increasing attention in urban studies. This is especially true in research on smart city infrastructure which has examined the integration of digitalization on urban infrastructure. Research, however, has mostly focused on the urban impact of ICTs, the role of large ICT companies in urban development and the applications and innovations they enable. For example, Luque (2014) notes that the smart grid, equipped with sensors for efficient metering, is one example of a "sociotechnical intervention that relies on utility networks, technological equipment and digital software" (Luque, 2014, p.160). At the same time, research on data centers has focused largely on theoretical analysis about the materiality of data infrastructure and resource extraction for data center operations.

While there has been limited empirical research on sociotechnical relationships of ICT infrastructure on urban development and the governance of these infrastructural systems, there have been notable contributions. Diguet & Lopez (2020) conducted extensive research on the data center spatial and energy landscape in the US and France. Researchers examined data center impacts in urban territories on issues related to landscape integration, renewable energy use, and development of residual heat networks. Diguet & Lopez (2020) argued that data centers have received limited attention from urban planners and that there is inadequate governmental oversight of data center development: "We have observed that data centers arrived, most of the time, without the public administration being able to anticipate their installation" (2019, p.110).

There has also been research on the ways data centers are impacting urban utilities. Researchers examined how data centers are claiming the energy resources of congested urban utilities while also providing valuable sources of heat for distribution to urban residents. Liberston et al. (2021) examines controversies surrounding the energy grid in Sweden which in recent years has experienced congestion and reduced grid capacity. Despite shortcomings of the electrical grid, the Swedish government continued to approve data center development creating additional strains on the energy grid. Researchers introduce the term "energy gentrification" to explore the implications of data centers receiving priority because of the energy grid's legal 'first come, first serve' mandate. Libertson et al (2021) argues the need to evaluate current policies on energy distribution to ensure local or regional businesses or initiatives are not inhibited because data centers claimed power first. Also in Sweden, Velkova (2016) conducted empirical research on the implications of data center residual heat. Data center residual heat had become a "commodity emerging from computation traffic" and was in the midst of replacing "old forms of energy supply" (Velkova, 2016, p.2). Velkova (2016) argues that by offering residual heat, data centers increase their influence by "validating" the production of continued data flows.

Information and Communications Technology, Smart Cities and Ubiquitous Computing

Research on ICTs and cities emerged in the early- 1990s because of growing interest and concern about the impacts and capabilities of computing and electronic devices on urban infrastructure (Mora & Deakin, 2019). And even before then, as Rutherford (2020) notes, many of the shifts in urban planning during the 20th century were motivated by the "belief in progress through technology" (Rutherford, 2020, p.157)—a dogma that has become prevalent since the advent of smart urbanization. Through a "critical data studies"(Dalton & Thatcher, 2014) lens, geographers and social scientists have examined smart cities and "ubiquitous computing"

(Crang & Graham, 2007) in different ways. Research has spanned issues on governance and knowledge production, the opportunities of ICT-enabled cities as it relates to sustainability, mobility, crowding, and increasingly, on the physical infrastructures behind the data.

The rapid pace of data growth has had significant impacts on digital infrastructure. Since the late 1990s, there has been proliferation and expansion of digital services. In 2011, reports indicated that "1.7 million billion bytes of data per minute were being generated globally" with estimates of a 40% increase per year (see Rial, 2013 in Kitchin, 2014, p. 70). The fast-paced advancements in cloud storage, automation, artificial intelligence, and internet of things have spurred intense data traffic growth and device deployment. These technological advancements have led to increase in smart cities, digital utilities, telehealth, self-driving vehicles. According to a 2018 Cisco report, cloud data center traffic "was set to reach 19.5 zettabytes (ZB) per year by 2021, up from 6.0 ZB per year in 2016" " (Cisco, 2018). In the report, there was also predictions that "IoT connections would reach 13.7 billion by 2021, up from 5.8 billion in 2016" (Cisco, 2018).

From a technological perspective, smart technologies and ubiquitous computing are changing the fabric of urban spaces: "ICT is rapidly being woven into new and existing urban policies, agendas, narratives and aspirations" (Karvonen et al., 2019, p.1). With IoT infrastructure "information about buildings, citizens, devices, and assets are processed to efficiently manage urban flows via real-time responses" (Stübinger & Schneider, 2020, p.1). Though this data may provide useful analytics, the increased use of devices in urban spaces has led to a "a radical expansion in the volume, range and granularity of the data being generated about people and places" (Kitchin, 2016, p. 2).

From a governance perspective, scholars have identified how smart city initiatives are incorporated into urban political, economic, and social goals. Caragliu et al. (2011) found there is positive association between urban wealth, human capital, accessibility to multimodal transport and the promotion of ICT infrastructure (Caragliu et al., 2011). Therefore, promotion of ICT in European countries is seen as an important economic agenda for maintaining social, economic, and environmental sustainability. Whereas other research has examined how corporations like IBM and Cisco push for "techno-centric" developments where technology and automation are seen as key to solving urban challenges (Kitchin, 2013; Söderström et al., 2014). There has also been discourse on which parties are involved in the roll-out of smart city initiatives. Joss (2018) notes that smart city initiatives can be difficult to evaluate because it is "not unusual for smart city initiatives to be spearheaded by economic development agencies or innovation agencies, rather than by traditional planning departments" (Joss, 2018, p. xvii).

While there has been varied discourse on both the innovations and consequences of ICTs and ubiquitous computing on cities, the materialities, spatialities and ecologies of ICT infrastructure have only recently begun to attract more attention while the governance and planning of such infrastructure has received even less. Pickren (2018) connects critical data studies with studies on materiality of computing infrastructures including their historical and geographical contexts as well as their environmental resource demands. Pickren argues that while research in critical data studies has revealed how ubiquitous computing is shaping daily life, researchers "have largely eschewed a deeper investigation into the production of the networked infrastructures that make these new ways of living possible in the first place" (Pickren, 2018, p. 226).

Cloud Geographies & Ecologies

Despite the apparent invisibilities of the internet or the "cloud," (Furlong, 2021, p. 190) the internet is supported by large infrastructures seeking specific geographic locations, robust telecommunications infrastructure, and ecological services to ensure business continuity. Furlong (2021) argues that studying the "materiality" of data center infrastructure is critical for recognizing the spatial, environmental, and social implications of data usage despite the illusion of invisibility.

Though data centers may not be as visible (or visually familiar) as commercial, retail or manufacturing industries, data centers are billion-dollar assets (Greenstein & Fang, 2020) with complex technological, political, economic and environmental requirements for determining where to construct their facilities (Dutch Data Center Association, 2020). Data center operators seek specific geographic locations for their facilities depending on the type of facility and the type of data being processed. Hyperscale data centers, generally operated by the largest tech companies including Google, Microsoft, AWS, Facebook and Apple, often seek connectivity and abundant energy supplies but seek more rural areas to build large warehouses and host their own data/ data storage. Colocation or multi-tenant data centers typically have multiple clients but provide all the necessary connectivity, energy, cooling, security, and space for companies to install their own servers. Colocation facilities tend to be in urban/suburban areas with proximity and access to robust telecommunications infrastructure, connectivity to sea cables and internet exchange points (Dutch Data Center Association, 2020). Additionally, to ensure "business continuity" (Poole, 2019) or "uptime" (Neudorfer, 2012) data center companies seek affordable and abundant energy resources, proximity to renewable energy to support sustainability goals (Dutch Data Center Association, 2020). Many colocation data centers prefer to be in proximity to large markets (i.e. financial, healthcare, retail) and customer base to reduce latency and to efficiently reach as many users and customers as possible (Dutch Data Center Association, 2020; Greenstein & Pan Fang, 2020). Other considerations include sociopolitical stability and low natural disaster risk to ensure infrastructure safety and reliability (Dutch Data Center Association, 2020; Sverdlik, 2016).

From an environmental standpoint, data center operations are inextricably linked to electricity grids and depend on electricity systems to power servers and for cooling equipment. Data centers contract megawatts of electricity for their operations (Miller, 2009). Data centers are always on, running 24 hours a day, 365 days of the year (Oró et al., 2015). Any loss of power—ranging from minute power dips, to equipment or powerline disruption, power outages from natural disasters or cybersecurity breaches—can damage equipment, compromise data center operations (Steman, 2018) and lead to significant financial loss (DiDio, 2021). Additionally, servers generate significant amounts of heat and require constant cooling energy (Wahlroos et al., 2017). To ensure continuous energy for servers, data communication and facility cooling, data centers build to protect themselves from outages or uncertainties (Keke, 2020). Data center companies invest in redundant power supply and cooling infrastructure to “support a single failure or requirement of that component” (Steman, 2018). Data centers often increase redundancy architecture by essentially doubling energy storage or cooling equipment (Hatzenbuehler, n.d.). For example, in addition to connections to the energy grid, data centers are equipped with uninterruptable power supply batteries (UPS) and diesel generators in case of failure of the power grid. Both infrastructures provide short-term power supply to the facilities servers if there is a grid failure. These redundancy requirements often increase the material footprint of the data centers as well as their energy needs (Steman, 2018). Data centers also very secure facilities with several layers of security to prevent vulnerabilities.

Cooling data center (servers) and removing heat is perhaps the central conundrum to data center operations at the heart of the resource consumption, as well as central to innovation. According to some estimates, cooling “to maintain IT equipment working in a safe and reliable manner…can account for up to 40% of the total energy consumption in a data center” (Capozzoli & Primiceri, 2015, p.485). Data centers often reference their power usage efficiency (PUE) to determine how much electricity is going toward powering IT equipment versus “ancillary” equipment such as cooling. The PUE ratio is defined as: (total electricity demand) / (IT equipment electricity demand) (Koronen et al., 2020). As Mytton (2021) notes, a PUE of 1.0 would be optimal as 100% of electricity was supporting IT equipment. As the number increases, the efficiency rate declines (Mytton, 2021, p. 2).

Additionally, cooling issues have said to account for the largest amount of server failures (Anandan & Ramalingam, 2008). There are multiple ways that data centers can cool their facilities and some data centers may have more than one system. There are two primary ways that data centers cool the facilities include air cooling and liquid cooling, although both use water. Most data centers use air cooling to remove heat (Capozzoli & Primiceri, 2015). Under this process, cool air produced by chilled water is from ambient environment flows through the facility, collects heat from servers and then the hot air is expelled from the plant or sent to residual heat grid. Another popular method is to use liquid cooling, in which cool water passes the servers, absorbs their heat, and expels the heat or reuses it.

By connecting to a district heating network, data centers can transfer their waste heat onto a grid which can then be used by nearby residents/households, offices, or other facilities in need of indoor heating. If successful, the data center heat source would be considered a sustainable energy source "if they make use of electricity of renewable energy sources" (ten Haaft, 2020,p.47) which experts envision would lead to less reliance on fossil-fuel based heating. However, there are complications. Some of the significant barriers to connecting data centers to district heat networks is the "low quality" of waste heat (Wahlroos et al., 2017, p.1229) which is often below 85 ^{o}C and "temperatures are too low for many applications and processes to exploit by conventional methods" (Wahlroos et al., 2018, p.1754).

Despite the calculated geographic and resource demands from tech companies, scholars have examined marketing schemes and limited transparency have obfuscated their operations. Holt and Vonderau (2015) note that though cloud companies, like Google, use marketing schemes to demonstrate commitment to climate change, environmental consciousness, and transparency, they often "work to conceal or obscure less picturesque dimensions of cloud infrastructure" (Holt & Vonderau, 2015, p.74). Additionally, they suggest many of these companies are "secretive" of the logistics and technical details of their operations. In reality, "data centers are information infrastructures hiding in plain sight" (Holt & Vonderau, 2015, p.74). Brodie (2020) studied data center infrastructure in Dublin. Data center companies settled in Dublin citing their need for cool climatic conditions to operate 'efficiently' and 'sustainably.' However, Brodie (2020) noted that temperature/ climate was nearly a negligible characteristic (several other European countries had similar climates). Instead, data centers operators were benefitting from a "generous tax climate" (Brodie, 2020, p. 1105) and favorable business deals supported by the Irish government to entice tech investment (Brodie, 2020). Despite the apparent "smoothness" of data center marketing, it acts as a cover for the complex and "messy agglomerations of public interests, private capital, and state power" (Brodie, 2020, p. 1099). Amoore (2016) suggests that the opaqueness of cloud infrastructure has allowed the ICT industry to bypass legal and bureaucratic regulations and now the political hurdle is to "wrest the cloud back into a form over which one can have oversight […], to make it comprehensible and accountable in democratic fora, and to render the cloud bureaucratically and juridically intelligible" (Amoore, 2016, p.9).

Methodology

This research follows a qualitative research approach to better understand the relationship between urban data center development, the spatial and environmental impacts on the energy grid or opportunities for residual heat and how this networked infrastructure is governed.

Amsterdam was selected as a case study to provide a framework for analyzing the spatial and environmental impacts of urban spaces and the challenges of governing this infrastructure. While the MRA compromises 32 municipalities and 2 provinces (North Holland and Flevoland). This research primarily examines data center development in the municipality of Amsterdam and Haarlemmermeer, both of which have experienced the greatest influx of data centers. To conduct this research: first, a literature review was developed. Primary and secondary sources were used to identify companies, organizations, government leaders involved with data center infrastructure in Amsterdam. Additionally, reports issued by national, provincial, and municipal legislators on data center planning considerations were evaluated and used to identify additional stakeholders.

A semi-structured interview guide was developed and used to conduct in-depth interviews to understand viewpoints of stakeholders involved in the technical components of smart data collection, data center logistics, operations, and sustainability, energy grid provisions as well as those involved in policy implementation and governance. The initial interviewees were found through online research as well as through an online panel discussion about data centers. Additional participants were found through the snowballing method. Participants were recruited through email (if available) or through LinkedIn messaging. Due to the pandemic, many of the interviews were held online (MS Teams) or over the phone. Two interviews were in person. Interviews were recorded with permission and transcribed verbatim using otter ai software. Interviews were then coded in Microsoft Word and Adobe PDF. Research and policy documents issued by trade associations; government entities were also analyzed. If required, the policy documents were translated using Deepl translation software. Additionally, Dutch news and articles on data centers were found through google searches in Dutch and then translated with Google translate. Research limitations may include potential misinterpretation of the technical processes in the ICT industry as well as missed information because of language barriers. Note: I also recognize this research project would not have been possible without the technology-enabled by data center infrastructure: the ability to conduct multiple interviews over MS Teams, the ability to translate large documents within minutes, to receive instant google search results and translate webpages and the ability to save documents and files on the cloud.

Results

Data centers in the Metropolitan Region Amsterdam

This section will explore the historical development of Amsterdam as data center hub. Additionally, it will explain where data centers are constructed, their local impact and how the data center industry is woven into initiatives and policy discussions.

In 1994, following the completion of the Amsterdam Internet Exchange (AMS-IX), the data center industry in Amsterdam started to expand. The AMS- IX created a critical network point for transcontinental internet activity and facilitated significant "digital traffic between the US and Europe" (*Dutch Data Centres Continue to Flourish, with Amsterdam Leading the Way.*, 2018). While the industry established roots in Amsterdam in the late 1990s to 2000s, the market accelerated in 2012 to accommodate growing demands for centralized data centers and cloud services by European markets (Interxion, 2014).

While not unique to Amsterdam, there have been market shifts that led to concentrated data center use and the growth of urban colocation data centers. Over the years, companies have reevaluated the cost of maintaining and ensuring privacy of their own IT equipment (Koronen et al., 2020). Additionally, the cloud providers offer flexible, low cost and highly scalable solutions for new or growing businesses who may not have the expertise or financial ability to maintain their own infrastructure or software. Since colocation data centers often have 'strategic partnerships' (Equinix, n.d.) or host servers from cloud providers, smaller businesses as well as very large and expanding companies can use cloud-providers in colocation sites and sit close to their business and/or to their customer base.

The colocation data center hubs emerged in urban/suburban pockets all over the world (Sverdlik, 2021). In Europe, Amsterdam is one of five urban regions that have become hotspots for the market. The other European markets include France, London, Paris, and Dublin (FLAP-D). In 2018, the MRA was the second leading multi-tenant/ colocation and hyperscale European data center market among the FLAP-D data center markets (Dutch Data Center Association, 2018, p. 9). Since the moratorium, the colocation market in Amsterdam has slightly slowed but there continues to be market interest (CBRE, 2020).

Though colocation data center markets have emerged in other Dutch cities, the MRA has attracted the largest share of the market. In 2021, MRA hosted 74% of the multi-tenant market in the Netherlands (Dutch Data Center Association, 2021). Interestingly, since 2016, reports indicate there has been a decline in data center companies and individual facilities, but an increase in the square meters of data floor space. In 2016, there were 206 data center facilities operated by 128 colocation providers with a net data floor surface of around 228,000 square meters. In 2021, there were 184 data center facilities with 96 colocation providers and a net data floor surface of 400,000 square meters (Dutch Data Center Association, 2021, p. 17). In the MRA, specifically, there are 105 data centers run by 67 companies with a total of data floor at 296,364 square meters.

As data floor increases, the region has also seen significant increase in electricity demands from data centers. In 2019, data centers represented 1.3 GW of installed capacity and about 3% of the electricity consumption in the Netherlands (Ministerie van Binnenlandse Zaken en

Koninkrijksrelatie, 2019). According to a 2021 report by Centraal Bureau voor de Statistiek (CBS), the "the supply of electricity to data centres increased by 66 percent over a period of two years. 2017, 1.6 billion kilowatt-hours (kWh) was supplied to data centres in the Netherlands. This had increased to 2.7 billion kWh in 2019" (CBS, 2021). The municipalities of Amsterdam and Haarlemmermeer have witnessed similar growth, in 2017, "764 gigawatt (764,000 megawatt) were supplied to data centers, in 2019, 1230 gigawatts (123,000 megawatt) were supplied to data centers" (CBS, 2021).

In the MRA, there are six campuses where data centers have emerged (Dutch Data Center Association, 2018). These include Amsterdam Science Park, Amsterdam West, South-East and North as well as Schipol Rijk, and Almere (Dutch Data Center Association, 2018, p. 18). Colocation data centers in the MRA region construct new facilities or renovate old industrial or unoccupied buildings (Pickren, 2018; Sanders, 2019). This has been visible in Amsterdam's Science Park. In 2019, Digital Realty-Interxion renovated a 35- year-old building that housed the computer/ data center through which the first Dutch email arrived (Interview 14, Sanders, 2019). And nearly a block away, Equinix constructed a windowless 70 meter-high tower (Geraedts et al., 2019).

Many of these locations are chosen because of their proximity to "fiber optic cables, IP carriers, internet exchanges" (Dutch Data Center Association, 2018) and telecommunications infrastructure. In identifying some of the other highlights of the Amsterdam market, a respondent said Amsterdam was an important point for internet connections because in Europe, many of the internet exchanges terminate in Amsterdam. Additionally, the Dutch power pricing is lower compared to Frankfurt and London which makes it an attractive place for colocation facilities and international companies looking to host their content in colocation facilities (Interview 5). Additionally, as data centers cluster they begin to form a market for future customers :

> *"Once you have a certain amount of customers together, we consider our data centers to be kind of the marketplace. Also, for customers to interact with each other. They all need each other. That's how you see how clusters of data centers start to develop over the years. And why it also makes sense for us to build our next data center [here]. Not somewhere in a remote area in North Netherlands, but also in close proximity of the existing data centers meeting in the region of Amsterdam. Even though we are now facing challenges in the end power infrastructure, still we have a need for expanding in the close proximity" (Interview 14).*

Some colocation data center companies may sit slightly outside of the hyperconnectivity zone because their customers have less strict requirements for latency and can therefore build in an area where land prices are lower (Interview 5). One company that operates outside of the six colocation campuses noted, “ we don't have a lot of financial customers because of that. Our target audience is well, the majority hyperscale customers and then also local retail business.” (Interview 5).

The data centers in the MRA region have arguably boosted economic competitiveness and have been incentivized to settle in the region by business entities at the national, provincial, and municipal levels. The Netherlands Foreign Investment Agency, a division of the Dutch Ministry of Economic Affairs and Climate Affairs, has spearheaded support for digital infrastructure through tax incentives and low energy costs (Proper, 2019). The province of North Holland also has a staff lead focused on international business and works with foreign tech/digital infrastructure companies to ensure the environment is enticing and suitable for foreign investment (Interview 1, Noord-Holland, n.d.). At the municipal level, there is the Amsterdam Economic Board (AEB), a public-private organization aimed at boosting economic activity and digitalization in the city. The Economic Board also runs Amsterdam Smart City initiatives (Amsterdam Economic Board, n.d.-a; Mills et al., 2021). From a governance perspective, data centers in Amsterdam have become symbolic infrastructure—representative of the country’s advanced digital foundation and future digital ambitions. In national, provincial, and municipal policy documents on data center spatial strategy highlight Amsterdam’s historical role in telecommunications infrastructure as well as the country’s ongoing commitment to sustain the digital economy and digital opportunities: “if you don't have that infrastructure, you don't have the internet with the speed we have right here. You don't have the ecosystem creator out in Amsterdam, doing all kinds of smart stuff, good stuff for the city and the future of the city, we wouldn't have the position we have here in the sense of livability of the city or, or the talent, wanting to be here or wanting to live here” (Interview 9)

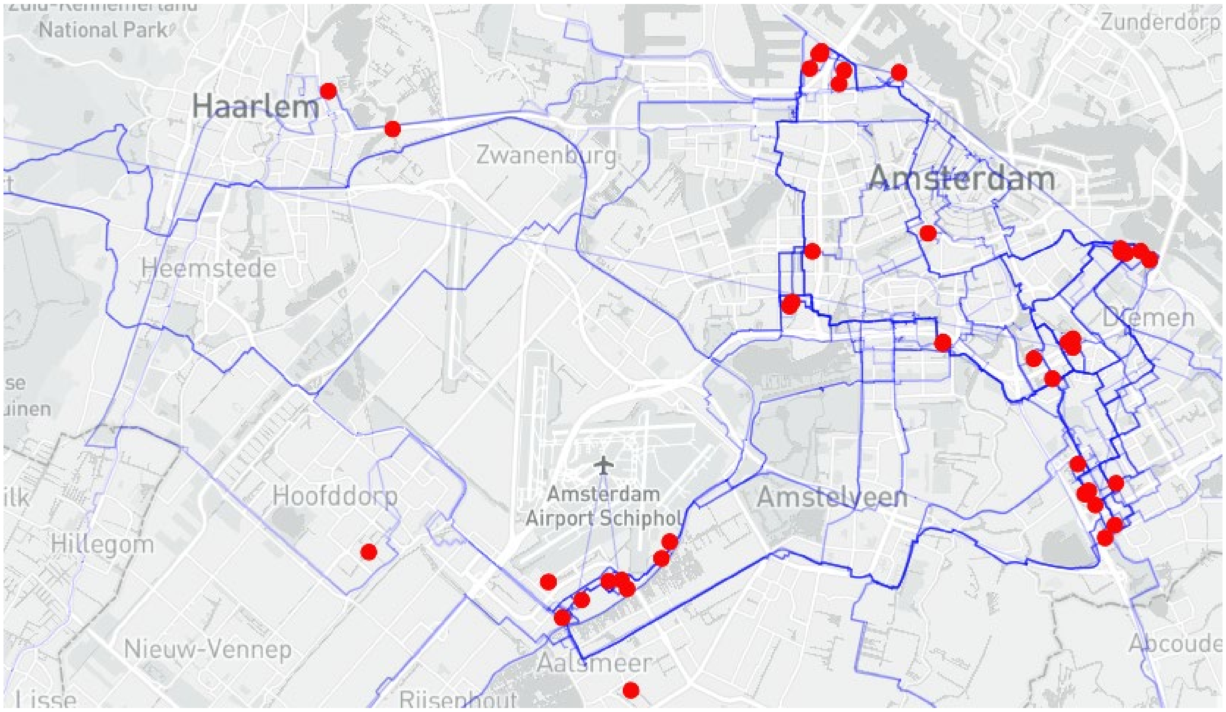

Figure 1. Amsterdam and Haarlemmnemer Data Center Map. Source: https://www.datacenterjournal.com/data-centers/netherlands/amsterdam/

Data center Ecosystem

While this research examined a small fraction of the many players involved in data center planning in the Amsterdam Metropolitan Region, this section will outline the entities involved in the Amsterdam's data center operations and governance.

Data Centers

Data center operators in the MRA region primarily consist of telecommunications operators and colocation providers. Though not an extensive list some companies with data centers in the region include: Equinix with nine data centers between Amsterdam and Schipol Rijk (Equinix, n.d.), Digital Realty-Interxion with 13 facilities (Interxion, n.d.), Global Switch has one data center with construction underway for a second (Global Switch, n.d.). Lumen, a telecommunications company with data center services has one facility (Lumen, n.d.), Verizon also has one facility but may likely operate servers at other colocation data centers. CyrusOne and Iron Mountain both have one facility and are located closer to Haarlem.

Data centers typically work with brokers to the find land to purchase or lease depending on the location (Interview 8). In Amsterdam, data centers collaborate with real estate firms such as CBRE and JLL to help find and negotiate lease (Interview 8, Dutch Data Center Association, 2021). Additionally, colocation data centers typically contract their energy from local grid operators prior to deciding or negotiating on location (Interview 9). Alliander, the parent company of local energy grid operator, Liander, noted that data centers request “20 mega-volt-amperes (MVA) to 80 MVA, which is comparable to the transport capacity of cities of 35,000 and 140,000 inhabitants. Data centers around Amsterdam already account for about 15 percent of the electricity consumption of all homes in the capital combined” (Alliander, 2019). In addition to receiving energy from the grid, data centers also require back-up energy supplies to prevent internet downtime in an emergency or blackout. Depending on the size of the data center, back-up energy supplies often consist of diesel generators or on-site energy storage batteries (Kordkheili et al., 2021)

Often overlooked in evaluating the colocation data center actor network are data center customers. This is because customer privacy is essential. ICT customers often decide to store their servers with data center operators based on the hyperconnectivity, power supply, power, and cooling redundancy, security, and privacy. In an interview with MTSprout, a managing director at Interxion, explained: “We don't always know what we're housing. This has to do with the privacy, security, and confidentiality of and for our customers. What is running on those servers and what is flowing through the data cabling, we do not always have a view of that. That way we can guarantee that privacy. That is why our customers specifically choose us” (de Zeeuw, 2021).

Figure 2. Equnix Data Center Science Park, Amsterdam

Industry Representatives

There are two main trade organizations that represent the business interests of data centers and related ICT infrastructure services across the Netherlands and in the MRA. These include the Dutch Data Center Association (DDA) and NL Digital. They are member-based organizations that provide industry news/ update for ICT industry representatives as well as information to external entities. Together, the organizations provide research about the data center market, inform policymakers and the public about data center operations, and help steer national, provincial, municipal policy development for data center regulations. The DDA was involved in the development and research for the 2019 National Data Center Strategy and the National Spatial and Environmental Planning Policy which has been incorporated into provincial and municipal data center strategies. The organizations have served as a liaison to data center industry. The organizations sounded the alarm about energy grid capacity shortages in the MRA. Additionally, they've influenced policy changes on residual heat categorization, to ensure that data center residual heat was categorized as a renewable energy source (NL Digital, 2019).

Government and Regulations

There are three layers of Dutch government that are most relevant to the conversations on data center spatial and environmental planning: national, provincial, and municipal. Generally, the national government is responsible for creating national strategic policy while the "the provinces are responsible for translating these guidelines into the regional context" (Government of the Netherlands, n.d.). Municipalities are responsible for implementation of the national and provincial goals through spatial planning and the environment (Government of the Netherlands, n.d.). In the MRA, the province of North Holland, is responsible for determining zoning guidelines for expansion of industrial, commercial, residential areas. They are also responsible for certain environmental permits and for ensuring space for wind parks (Government of the Netherlands, n.d.). The municipality of Amsterdam is the "owner of land and infrastructure in the public space, both above and below ground" (Gementee Amsterdam et al., 2022). Governments also work alongside regulatory agencies. The municipality of Amsterdam and the Province of North Holland, work with the North Sea Canal Area Environment Agency (Omgevingsdienst Noordzeekanaalgebied). This is a regional regulatory agency that oversees environmental permitting and ensures that companies are complying with current environmental regulation on various issues including construction, infrastructural and soil safety, as well issues of noise and sustainability (Omgevingsdienst Noordzeekanaalgebied, n.d.). The municipality and province also work with water utilities, such waternet, on issues related to drinking and wastewater. Waternet is also a relevant actor in the discussions on residual heat since water has such high capacity for heat and cooling, it was important for the organization to be involved in discussions of grid development (Interview 4).

Grid Operators

Data centers rely on energy grids to power their servers and facilities (Alliander, 2019). In the Amsterdam Metropolitan Region, Liander serves as the Distribution Systems Operator (DSO) which provides electricity (under 80 MVA) to commercial and residential properties as well as data centers in the MRA. TenneT, a Transmission System Operator provides high-voltage energy (over 80 MVA). TenneT is responsible for transporting energy to Liander for distribution. This transport happens at substations where the electricity on high-voltage or transmission grid is reduced from 150kV from 50, 20 or 10kV to then be used on Liander's distribution grid.

Table 1

Kilovolt (kV)	A measure of 'apparent power,' an assumption that not all power will be converted to "useful work." More importantly, this is the unit grid operators use to describe their electrical transport capacity. kV is multiplied by a power factor of 0.8 to convert to kilowatt hours. kVA to kW is: kVA x (0.8)pf = kW
Kilowatt (kW)	A measure of "actual power," the amount of power "converted into useful, working output" This is often used to describe electrical supply and demand. Data centers contract energy in megawatts (MW) with the grid operator, consult with 1000 kW = 1 Megawatt (MW) 1000 MW = 1 Gigawatt (GW)
Petajoules	A unit of energy. Often used by CBS Statistics. 1 PJ= 1,000,000 GW

Table 1. Explanation of Energy Units in Data Center Operations. Source: (Generator Power, 2018)

The logistics and spatial requirements of energy grid infrastructure add additional complexity to the role of the grid operator and to infrastructural considerations of data centers. Grid investments take considerable time to build. Construction for a new Liander substation in the MRA, can take between five and seven years (Gementee Amsterdam & Liander, 2021) and require on average 3,200 m^2 of space. Additionally, substation cables that connect from the substation to the customer are about 27 meters wide and therefore require spatial evaluations below ground (Gementee Amsterdam et al., 2022).

Since Liander and TenneT are public utilities, they are bound to strict legal and financial obligations. They are regulated by the Authority for Consumers and Markets (ACM) to ensure that legal and financial obligations are met. Liander and Tennet are obligated to: "connect producers and consumers to electricity and gas grids and carry out transportation for customers." The operators must also "ensure non-discriminatory access to the grids" (Netbeheer Nederland, 2019, p. 7). This means companies are not permitted to disclose customer names and are legally bound to a "first come, first serve" policy (Hut, 2021).

While there is significant need for grid investments, the grid operators must be certain that the new infrastructure will be used, or else face financial penalties by the ACM for faulty investment decisions. The significant demand for energy alongside uncertainties about data center planning has made this particularly challenging for grid operators.

> "They [ACM] are monitoring our investments. And we are being benchmarked with all the other grid operators. And if we if we invest millions, and the data centers, won't come then we get some kind of not a fee, but our rates have to drop. It's really the way we are watched by the government enables a really defensive investment strategy. And if we aren't sure the benefits will come for the investment and, and its logic because it's not our own money. It's money from the people. We have to spend it right, I guess…. That it holds us back for now to invest really far in front. The real, the real question of data center is a question on power. So for data centers, we basically just wait till they start asking" (Interview 13).

Data Center Spatial Policy Development

In the Netherlands and specifically in the MRA region, strains on the energy grid were the impetus to develop data center business and spatial strategies (Alliander, 2019). In 2018, following concerns about grid capacity in Schiphol and across the Amsterdam Metropolitan Region (Bakkeren, 2019), there was an effort to create a national data center strategy. Until this point, colocation data centers were considered standard businesses: "data centers are companies. We make company policy; we don't usually make data center policy or whatever kind of field or branch. We don't make specific policy for that" (Interview 1). From a zoning perspective, data centers were considered to have a low environmental impact and would've likely be designated as category 2 business (Oosten, 2021) by the Agency for Public Works and Water Management (*Rijkswaterstaat*) because of limited noise, odor or light nuisance (Sintemaartensdijk, 2020). For this reason, the industry growth had largely gone unnoticed.

There were reports at the time that stakeholders were not aware of data center energy consumption. According to an article published in a leading Dutch newspaper, NRC Handelsblad, important stakeholders had not been aware of the energy consumption of data centers (Bakkeren, 2019). Minister Wiebes, the Minister of Economic Affairs and Climate (EZK) had indicated that energy consumption was not managed. The reporter also contacted Central Bureau of Statistics (*Centraal Bureau voor de Statistiek (CBS)*) and Netherlands Environmental Assessment Agency (*Planbureau voor de Leefomgeving (PBL)*). Both organizations indicated they were unaware of data center energy use (Bakkeren, 2019). Alliander reported that prior to the publication of a data center strategy, the company had been "regularly surprised by requests at a certain location. The regular spare capacity at transformer stations is usually exhausted after the connection of one average data center" (Alliander, 2019).

In response to increasing concern about industry needs and "alleged" energy bottlenecks, there was a decision to create a national data center strategy (Ministerie van Binnenlandse Zaken en Koninkrijksrelatie, 2019). In March 2019, the Spatial Economic Development Strategy (*Ruimtelijk-Economische Ontwikkelstrategie*)— a partnership of three national ministries, several provincial and municipal governments as well as regional economic boards— along with stakeholders such as the Dutch Data Center Association and energy grid operators created the "Roadmap 2030 for the growth of data centers in the Netherlands" *(Ruimtelijke Strategie Datacenters Routekaart 2030 voor de groei van datacenters in Nederland).*

The *Roadmap 2030* outlined several agenda items. The spatial strategies include permitting additional colocation clustering in the MRA, consideration of expansion of colocation data center construction in the Greater Amsterdam area (including Almere - Zeewolde - Lelystad – Dronten); allowing additional hyperscale construction in Middenmeer and Eemshaven (where Google and Microsoft have facilities) and evaluating additional opportunities in South Holland. Long term plans in the report include the development of a new data center cluster area in the western part of Amsterdam (Ministerie van Binnenlandse Zaken en Koninkrijksrelatie, 2019).

Soon after, the National Strategy on Spatial Planning and the Environment (NOVI), which is part of the new Environmental Act (*Omgevingswet*) that is set to go into effect in 2023, outlined the responsibilities of the national, provincial, and municipal governments in spatial planning and environmental permitting. Their recommendations on data center spatial strategy were largely based on the Roadmap 2030 but stated that data center development could occur under three primary conditions: where "energy demand could be sustainably met via current or future energy networks…there are possibilities to supply waste heat to heat networks in urban areas; and the requirements for digital connectivity that are set by players on the market can be met" (Oosten, 2021). Additionally, the NOVI document stressed that "the local levels of government bear primary responsibility for regional establishment policy of businesses and hence also data centers. These lower governments can include the establishment of data centers in their integrated plans" (Rijksoverheid, 2019).

The roadmap provided some guidance on future expectations for data center growth across the country, but municipal concerns persisted. There were concerns that the existing energy grid could not accommodate Amsterdam's future growth: welcoming new data centers, participating in energy transition initiatives, increasing housing supply, and electrifying mobility services. Furthermore, Amsterdam continued to struggle with how to regulate data center development and address concerns about energy bottlenecks. In addition to not having control over zoning regulations of data centers, municipal governments had limited oversight on energy distribution. In a press release, the municipalities stated the difficulties in governing data center infrastructure: "at the moment, it is hardly possible to control the location of data centers, because they almost always fit in with the zoning plans and Tennet and Liander have an obligation to supply electricity" (Gementee Amsterdam, 2019).

In response to these local concerns, in June 2019, the municipalities of Amsterdam and Haarlemmermeer, announced a one-year moratorium to give municipal governments more time to consider data center construction, reevaluate the bottlenecks on the energy grid and plan for a data center sustainability strategy: such as mandating residual heat network connections.

After the moratorium, there was a cascade of policy documents. In June 2020, Amsterdam and Haarlemmermeer published separate but similar policy documents which referenced the relevant regional plans from Roadmap 2030 as well as new initiatives that had been drafted during the moratorium. While Haarlemmermeer signed the new policies into law, the municipality of Amsterdam has not yet generated legislation. Rather, the municipality is using control over leasing to permit data center development (Oosten et al., 2021). Table 2 outlines many of the new regulations in place. The City of Amsterdam, Liander and TenneT also released the Electricity Supply Amsterdam program (Programma Elektriciteit Voorziening Amsterdam) an initiative to understand current and future local grid demand and plan for future grid expansions. Additionally, the Amsterdam Economic Board spearheaded a public-private partnership called Lower Energy Acceleration Program (LEAP) intended to encourage energy efficiency operations within the ICT industry and included an initiative to require servers to go into sleep mode.

Table 2: Governance and Policy Decisions Post Moratorium

Governance	Responsibilities	Policy Decisions Post-Moratorium
National	-Oversight of the National Environmental Vision (NOVI) which includes: - outlining areas for data center growth nationwide (NOVI section 2.6, p.102-3) - Create pro-business climate - Introduce legislation/ regulation for sustainable data center development including rules on mandatory waste heat - Promote renewable energy development -Regulation of energy grid (ensuring mandatory connections to customers) - Through the Dept of Public Works (Rijkswaterstaat), permit extractions for surface water	- Hyperscale clusters in Middenmeer and Eemshaven; hyperconnectivity (colocation) clusters continue in Amsterdam; plan for hyperconnectivity cluster west of MRA (ie Almere)
Provincial	- Authorize locations for data center growth in province - Support regional economy - Ensure compliance to environmental regulations in partnership with the North Sea Canal Zone - Implement Environmental Management Act	- Promote hyperconnectivity cluster in Almere (to offset pressure on Amsterdam) - Coordinate with municipalities about data center impact on environment, multipurpose use, and aesthetic embedding in space- through environmental regulation and enforcement

		- Promote voluntary sustainability initiatives with DCs such as "circularity of the buildings and materials used" (Province of NH) -Assist with Residual Heat Network research and implementation
Municipal	-"First responsible authority" in data center construction because of control of zoning regulations as outlined by the National government through the National Environmental Vision (NOVI section 2.6, p.102)	-Definition of growth limits: Maximum increase of 670 megavolt ampere until 2030; Maximum annual growth of 67 MVA (Gementee Amsterdam, 2020; Oosten et al., 2021) - Designated four business park zones with room for additional data center growth/clustering: Amstel III (South-East), Haven/ Havenstad (North-West), Schinkelkwartier (South) and Science Park (East). - "Intensive use of space," is required to reduce building footprint. Buildings must be multi-level instead of single story. Operators need to consult municipality about height. Data centers can be constructed underground. -Spatial integration: building should have beneficial "architectural qualities" so as not to look "conspicuous"(Gementee Amsterdam, 2020, p. 24). Additionally, there should be consideration of how to 10 or 20 kV energy grid cables underground. -Mixed use of space: ground floor should be multi-purposed such as for food retail, public facilities, or local businesses. This applies to data centers in business parks- where data centers are located. -In collaboration with energy grid operators: colocation facilities larger than 80 MVA must construct their own 150 kV purchase station; and connect to TenneT. - Mandatory requirement to construct residual heat connection. - Construct renewable energy infrastructure on data center buildings (such as solar panels on roofs). Recommended to use a non-fossil fuel source in case of emergency power outage rather than diesel generators. -Continue Power Purchase Agreements (long-term investment in renewable energy infrastructure) -Limit drinking water usage for coolin by using non-potable sources such as wastewater, surface water, ground water.
Amsterdam Economic Board + other business actors	-Promote economic activity in MRA	-Low Energy Acceleration Program: recommendations to improve energy efficiency of servers -Power Usage Effectiveness no more than 1,2

Table 2. Requirements for Data Center Development in Amsterdam: Post Moratorium. Sources: Gementee Amsterdam (2020), Provincie Noord Holland (2021), Oosten et al. (2021).

The regulations have provided some guidance though participants indicated that the process was evolving and required constant communication between stakeholders to the evaluate ongoing and future projects. As one participant noted:

> "There is some sense of uncertainty about who is the--what is the proper entity to deal with the data centers concerning or relating to the size of such an initiative. But what we have done is that we've put all the relevant parties together and to discuss this continually, where are we? what is going on? Who is asking for something and how do we deal with it? So it is not necessarily that it's solely a municipal thing or provincial thing we are interacting with each other on how to deal with it." (Interview 9)

New paths on data center governance

Grid Expansion

Amsterdam's spatial and economic growth as well as the continued growth of data centers, relies on the construction of additional substations (Gementee Amsterdam, 2020; Gementee Amsterdam & Liander, 2021). The development of program EVA through the partnership between Liander, TenneT and the municipality of Amsterdam was one of first collaborations between the city and energy grid operators. At the time of publication, a councilmember for the city of Amsterdam wrote, "this situation calls for a rigorously different way of working together. We will no longer negotiate with each other in our own interest. We have a shared task" (Gementee Amsterdam, 2021).

Prior to the moratorium, the municipalities of Amsterdam and Haarlemmermeer were allowing data center construction (since they fit into business park zoning requirements) but were not permitting substation construction because of their higher industrial zoning category. This prevented substation development and led to shortages in space for future grid expansion as well as concerns about lack of space underground (Interview 10, Interview 13, Gementee Amsterdam et al., 2022). In the announcement of the partnership, a representative from TenneT, wrote: "the designated space, both above and below ground, partly determines the speed of the grid expansion. Finding suitable locations really should be a priority" (Gementee Amsterdam et al., 2022).

There were two main changes in the moratorium to account for grid capacity shortages and concerns about lack of underground space for cables. In the past, only hyperscale data centers had a connection to Tennet, however, more recently, colocation data centers are seeking increased amounts of electricity. Data centers are requesting increased energy loads which Liander is unable to fulfill because of capacity shortages. The moratorium required that facilities requesting more than 80 MW, construct their own 150 kv station and shift their contract to TenneT's high-voltage grid. This would prevent Liander's grid from being completely utilized by a data center: "If there is a data center which asks, 80 MVA, the whole transformer is 100% for one customer so does the public have to pay for one transformer?" (Interview 13).

In addition, there is an expectation that data centers evaluate the underground capacity for electricity cables since the underground spatial capacity is also limited. One data center operator noted: "And also on the underground, it's getting quite full as well. So, planning new cable route is already a challenge in itself. But that's the future ahead of us. So that will happen" (Interview 14).

A Liander participant expressed concern that the plan may have been developed too late, but that it was a good step:

> “And we predict what now is happening in Amsterdam: the grid is full and we we weren't able to expand the grids because there isn't any space and we can't make space. The grid operators can't say move along with your buildings. We need space. So Amsterdam it's also not easy for a city to do so probably we started too late maybe I don't know” (Interview 13)

Spatial policies and collaborations with stakeholders (such as program EVA) have provided an outline of expectations for future energy needs and grid expansions. However, there concerns about how to manage the uncertainty of the data center market with the financial and spatial demands of energy grid infrastructure. This is especially true as local, provincial, and national governments negotiate on the rules, regulations, and influence on the data center industry.

As outlined by national, provincial, and municipal strategy reports, the growth of the data center market in the MRA hinges on the ability to develop a fourth hyperconnectivity cluster in Almere, in the Province of Flevoland. The plan was intended to relieve spatial and energy stress in Amsterdam and Haarlemmermeer municipalities after 2030. As a result of these planning decisions, energy grid operators started drafting plans to expand the grid to accommodate future energy needs in Almere. However, there are now uncertainties about whether the city of Almere will allow for the hyperconnectivity cluster (Interview 9). While there was support for the project, including initial construction on nearly 200 hectares of land, consultation with energy grid operators and the DDA, the Almere municipality decided in January 2022 to pause construction until further research was completed (Clahsen, 2022). The municipality argued that recent political controversies surrounding a hyperscale Meta (Facebook) data center in Zeewolde, and lack of clarity on central and provincial government’s lobbying/political influence, were reason to put a hold on project development (Clahsen, 2022).

The decision, however, has impacts on the trajectory of data center spatial planning and energy grid expansion. This may mean, for example, that the existing national, provincial, and municipal spatial strategies need to be revised (Clahsen, 2022) and has ramifications for the infrastructure development. As one participant explained, “each layer of government has its own, way of influencing, influencing spatial development and spatial planning and with each his own rights, mostly clear, but mostly also not. That makes it quite disturbing” (Interview 9). Unclear guidance on data center spatial planning also has a direct impact on planning for energy grid expansion.

The news about Almere makes planning for future grid expansion precarious. In discussing the sudden changes to the Almere plans, a participant explained that the ‘best’ scenario would be for government to: “get in line of complying[...] just point out, just say, till 2030: Amsterdam and Harlemmemer, after 2030 is Almere, I don't care. Just name it then. Don't make us bleed when they [data centers] don't come because we can't predict it” (Interview 13).

Residual Heat

Though the moratorium mandated that new data centers have the capability and necessary equipment to connect to a residual heat network, the underground network in the city has not yet been built. Therefore, data centers are yet not able to provide the residual heat.

Among the participants, there appeared to be agreement that developing a residual heat network was an opportunity for data centers to be sustainable and provide beneficial resource to Amsterdam. However, there were other participants who questioned the practicality of such a network. While there are pilot programs and ongoing discussions about the possibility of building residual heat networks, many interviewees suggested there were major legal and financial barriers to the development of such infrastructure. The interviews also suggested there was uncertainty about which entity or entities should be responsible for constructing and managing the network.

A senior policy advisor for economic affairs for the City of Amsterdam expressed concern about the social and physical feasibility of heating areas in the Amsterdam and lack of economic incentives for third parties to want to build and manage a residual heat network:

> "[The municipality] can allow it, but then the question arises who pays for residual heating network, so, if you let it be built by third party, that party will [need to] have some assurances that he can make a feasible business case out of it" (Interview 9).

The participant from the Province of North Holland felt conflicted about who was responsible for the construction and management of a residual heat network. The participant said that data centers 'pride' themselves on sustainability measures and are therefore willing to contribute to residual heat but on the other hand, there is very little infrastructure to support it in the first place: "The problem now is not enough infrastructure. And that is something that is difficult, I have to admit, the data centers are not really to blame here. I guess there's no one to blame" (Interview 1)

An employee who works for an Amsterdam water utility and had been involved in discussions about residual heat network construction said that money and political indifference were the two main reasons for lack of movement on district heating networks. The cost for the municipality to construct the needed 3,000 kilometers of heat network pipes would be enormous. Additionally, the municipality preferred to serve as a mediator between commercial/ residential developers and network construction rather than be involved in incentivizing the development of the network. However, the participant was concerned with this market approach. If Amsterdam intends to go fossil free by 2040 and doesn't take any action now, then it will be forced to make a lot of expensive of difficult changes in the future.

> “My personal opinion is that district heating and cooling network would be a public utility since everybody needs to be able to heat and cool their house in a sustainable and affordable way. So it has all the characteristics of a public utility. The municipality of Amsterdam has a different view it seems that they have a different view they [are] trying to let the market solve everything. So, they just generate projects and transformation projects for new housing projects. They can tender within their own market they hope that it will somehow lead to the to a solution for the whole city. But I'm very worried about that way of thinking” (Interview 4)

Governance

Since data center operations are intertwined in energy and urban infrastructure and because digital services are an essential feature of daily life, governance has become challenging and contentious. Furthermore, lack of transparency from the industry (and even within the industry) has made data center governance difficult.

Data center operators and industry representatives argue that criticisms and efforts to dissuade data center development are often misguided measures. Representatives from the DDA argue that critiques about data center spatial footprints or data center energy usage, ignore the fact that data centers are essential for digital activities, provide universal services and are the “beating heart of our digital economy and our digital government” (Tues, 2022). Furthermore, they argue that industry is invested in supporting the energy transition and at the forefront of renewable energy investment (Interview 8). Another participant argued that perceptions and news about the energy and water consumption were often blown out of proportion and acknowledged that the public was unaware of the physical infrastructure behind internet provisions: the “discussion, of course, is taken to extremes where people may have opinions now like we don't need data centers, they only they only spoil energy. We sometimes make a joke that people say, ‘I don't need data centers because I only work in the cloud these days’” (Interview 14). Others suggested that data center industry often governments were slow to respond to the ICT industry and in some cases were implementing regressive policy choices, instead of supporting the innovation of the industry:

> “Unfortunately, because the pace of technological change moves so fast, governments tend to fall behind, then they tend to regulate in a reactionary way, they're almost trying to leapfrog and anticipate, you know, what's going to happen?— so that they don't get stuck behind” (Interview 5).

However, since data centers protect information to stay competitive, there has also been limited transparency on energy utilization, consumption, efficiency which has made it difficult to govern effectively. Some of the metrics used to measure data center efficiency are not always clear. For example, data centers have different approaches for measuring energy and water usage. A data center can appear to have a low PUE (power usage effectiveness) but may be using significant amounts of water for cooling. Whereas a data center with a higher PUE, maybe using more electricity and less water: “so the PUE, for example, has different categories. And at this moment, nobody is saying, okay, I am using category one, two, or three. Now the PUE is this, so you don't know which category. So it needs to be more transparent” (Interview 12).

CBS published their first report on data center energy use (between 2017 and 2019) and noted that “electricity supply from the national grid gives a better picture than estimates based on capacity, because the exact capacity, efficiency and capacity utilisation rate of most data centres are unknown”(CBS, 2021). Participants noted that it was difficult to get specific information from data centers including future plans, power and water usage (Interview 1; Interview 13). One interviewee stressed that lack of information has made data centers difficult to govern:

> “When looking at planning and when looking at the sustainability impact of data centers, the current level of insight and transparency that decision makers, that regulators, that politicians have, is falling absolutely short of what is needed to be able to make an informed decision. At the moment, we as society cannot assess properly the carbon… the environmental impact. And as a result of that, it is very challenging to make your decision” (Interview 7).

Contesting responsibilities in the data center

Governance for colocation data centers is also complex since regulators are negotiating with data center operators who are shielding their customers

Prior to and during the moratorium, there were initiatives to improve the energy efficiency of data centers. However, data center operators and the DDA have long been defensive of these efforts. The Dutch Data Center Association, and colocation operators argue that their customers (ie those installing the servers) should be responsible for ensuring that their applications, platforms and IT equipment are efficient. As one data center participant said: “We try to incentivize our customers for example, to redo their hardware platforms… if you save power, you save more space, and if you save more space... You don't need to build as many data centers as we do today” (Interview 6). Until then, they argue, that have agreements with their customers to offer them uninterrupted power.

Some of the post-moratorium requirements were obligations for data centers to have a 1.2 PUE and to participate in the LEAP initiatives, including requiring servers go into “eco” or “power saving mode” when not in use (Amsterdam Economic Board, n.d.-b). Recently, the City of Amsterdam and North Sea Canal Zone regulatory agency announced they would start issuing fines for data center operators that didn’t reduce their power management on servers (Judge, 2022).

Data centers rebutted this arguing that they had made contractual agreements with customers about energy allocations. Additionally, operators argued they were not able nor they responsible for managing their customer’s hardware. Instead, they proposed sending a letter to their customers notifying them about regulations and asking them to make hardware changes. The city and regulatory agency are expected to continue issuing fines despite opposition (Judge, 2022).

Conclusion

During years of stealthy growth, data centers propelled Amsterdam into the digital age while also transforming the urban landscape above and below ground. For years, the industry grew without much notice or cause for concern. When suddenly alarms sounded about shortages on the energy grid, municipal and provincial governments sprang into action in an attempt to steer an industry that had already taken firm roots.

Through a sociotechnical lens, this research has attempted to examine the impacts of data centers on urban spatial planning, the provisions of the local energy grid and the complications of governing layered and networked digital infrastructure. This paper first explored the growth of the colocation market in the MRA which have been attracted to region with reliable internet and energy connections as well as business support from all layers of Dutch government. The signs suggest that the data center market expanded significantly between 2016 and 2019, both in data floor space and in energy requests. Next, there was an overview of the key actors involved in data center operations, their responsibilities, and limits of influence. The article then examined the origins of the data center spatial strategy and the new regulations that emerged following the moratorium in Amsterdam and Haarlemmermeer. The discussion section focused on some the opportunities and hurdles of the new regulations specifically as they relate to energy grid construction and residual heat development. The discussion section concluded with identifying some of the debates and challenges of governance that are related to questions of responsibility and transparency. There are three primary findings.

Energy

The colocation market in the MRA has become a sought-after location for data centers seeking proximity to reliable telecommunications infrastructure and internet exchanges as well as affordable energy supplies. As Pickren (2018) and Brodie (2020) discuss the ways in which data centers capitalize on "ready-built, infrastructure." While telecommunications/ data center infrastructure are private enterprises they are "entangled" in public utilities: "private high-tech companies require and instrumentalize the energy and fiber optic resources of a given territory" (Brodie, 2020, p. 1106). Similarly, data centers have depended on the reliability of the energy grid to support their enterprise, attract more clients, and perhaps even expand their operations.

Infrastructure- Grid Development

Data centers in Amsterdam have had notable impacts on local infrastructure and local governance of the grid. This includes major and expensive expansions of the energy grid as well as new evaluations of the underground capacity for energy cables. On one hand, the challenges of creating infrastructure to support data centers has begun to facilitate cooperation between fragmented stakeholders like grid operators and municipalities, ensuring the zoning and space are available. On the other, the potential development of a residual heat network appears to have a more piecemeal future without financial support and governance from municipal leadership. Many of the difficulties of planning for infrastructural developments continue to stem from issues of transparency in the industry.

Transparency

Despite ongoing conversations and introduction of new regulations, there continues to be significant confusion and lack of clarity about the industry and even within the industry. Interviews revealed that there is limited information about specific energy or water use from data centers which makes it difficult to create effective regulations. This relates to Amoore (2016) who noted that lack of transparency in the industry has made it difficult to "wrest the cloud back into a form over which one can have oversight" (Amoore, 2016, p.9). Research also revealed the complications of governing colocation facilities. Unlike a hyperscale facility which represents one entity, colocation facilities have thousands of customers. While there have been attempts to govern data center efficiency, colocation data centers argue that it is the responsibility of their customers to update their algorithms, applications, and IT equipment. This, then means there is another layer of unknown. Understanding the physical and spatial requirements has led to some understanding of data center operations but more needs to be investigated.

Data center companies and industry representatives argue they receive unjustified criticisms about their spatial footprint and energy requirements. Industry representatives argue that data centers provide the infrastructure to support the digital services that governments, industries, and the public, depend on. Data centers also serve as enablers of the energy transition through grid transformations. These arguments are hard to protest given that they are so fundamentally true. Karvonen et al. (2018) notes digitalization is invisibly “woven” into urban ideals but that there is “a need to get inside smart cities to reveal the influence of digitalization on broader urban dynamics” (Karvonen et al., 2018, p. 1). In Amsterdam, invisible digital infrastructure has become (more) visible through its impacts on space and energy grids. However, the influence of digitalization is so vast that any legislative controls on the industry are viewed as a potential hamper to innovative digital solutions. Though there is a desire to control data center’s mushrooming development, as seen in Dutch national, provincial, and municipal policies on data center spatial planning, there is also recognition that data centers enable the digital capabilities that the country rely on.

Future research could involve more in-depth research on residual heat network as well as specific clusters of data centers and their local impacts. Other valuable research might involve a study on the ‘supply chain’ of data, additionally there could be more in-depth research on the relationships between colocation customers and the data centers.

Through a sociotechnical, networked analysis approach, this research revealed new insights about the impacts of data centers on the energy grid, the complexity of planning energy grid expansion amid ongoing political confusion about data center integration. While Dutch government sees data centers as an important feature in recognizing digital goals, they also face obstacles in preparing infrastructure and governing a rapidly evolving industry with limited transparency.

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Appendix I

Interview 1	Economic Policy Advisor, Province North Holland	48 min
Interview 2	Engineer, Responsible Sensing Lab	40 min
Interview 3	Project Coordinator, Responsible Sensing Lab	35 min
Interview 4	Researcher, Waternet	1 hr
Interview 5	Employee, Lumen Technologies	1 hr
Interview 6	Operations Managers, Iron Mountain	45 min
Interview 7	Executive, Sustainable Digital Infrastructure Association	32 min
Interview 8	Communications employee, Dutch Data Center Association,	1 hr
Interview 9	Deputy Head, Entrepreneurial climate economic policy advisor City of Amsterdam	51 min
Interview 10	Account Manager, TenneT	52 min
Interview 11	Researcher, PBL	36 min
Interview 12	Global Energy Efficiency Program Manager, Equinix	40 min
Interview 13	Regional Lead, Liander	1 hour
Interview 14	Manager, Interxion	50 min

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