Data centers and the city. The territorial impacts of the growing data economy, with a focus on Italy.

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The present paper focuses on the study of the multiple impacts that the digital economy, which is expanding rapidly today, has and may have in the future on territories, with a particular focus on the Italian context and on the implementation of Data Centers (DCs), a facilities used for the remote storage, processing, or distribution of large amounts of data.
In this context, there is a pressing need for in-depth research and multifaceted discourse on the urban and regional challenges

1. Introduction

In the field of urbanism, the debate in recent decades has often revolved around the concept of the 'smart city' (Kunzmann, 2014; Zubizarreta et al., 2015), which is mainly characterised and described in terms of networks, flows, services and digital platforms, all concepts linked to immateriality. This type of narrative has very often left in the background a reflection on the physical impact of all the infrastructure necessary to make the smart city work, and also on the social and political implications of this new reality (Cournet, Sanaan Bensi, 2023). A similar phenomenon occurs in the development of artificial intelligence (AI). While various aspects of AI for and in urban planning are explored, ranging from its practical applications to the ethical considerations required for responsible deployment (Wang, Yorke-Smith, 2025), the territorial impact of these technologies is often overlooked.

The present study aims to examine the multiple impacts of the rapidly expanding digital economy *of DCs location to enhance public knowledge and informed decision-making processes. This encompasses both the physical impact on territories and the implications for urban governance and socioeconomic aspects. This issue is of particular urgency in Italy. As the country emerges as a significant player in the European DC landscape, the absence of clear regulations gives rise to questions concerning the territorial and strategic planning of these infrastructures.*

on territories focusing on the implementation of Data Centers (DCs), facilities that houses an IT infrastructure for the creation, execution, storage, and delivery of data, applications and services.

The phenomenon has emerged recently in Italy and is expanding rapidly, which has significant implications for urban and territorial planning. However, difficulties in identifying and quantifying the impacts and benefits of DCs are revealed when confronted with public bodies involved in the development of these infrastructures. Thus, it is imperative to spatialise this phenomenon and facilitate more informed decision-making processes. To this end, we have launched a research project entitled 'ProdAction. The New Territories of Data Centers'[1] with the aim to enhance public comprehension of the challenges posed by DCs. The project has a geographical focus on the Milan metropolitan area (Italy) and is organised around three distinct operations. At the local level, the first step is to map existing and planned data centres. This is achieved by analysing urban planning documents and environmental approvals, as well as industry reports and press articles. Furthermore, a series of workshops and interviews were organised in order to gather direct information and facilitate dialogue between the various stakeholders involved (public bodies, designers, operators). The objective of these activities is to provide policy makers with some planning recommendations to inform the public and political debate about new, more stringent regulations at regional and national levels. At the same time, an interdisciplinary literature review on the topic and case studies analysis has been initiated to identify critical issues and potential areas for improvement. This paper makes a significant contribution to disciplinary reflections by proposing a more comprehensive territorial view informed by the urban planning discipline that is generally lacking in the present literature about DCs. Furthermore, it integrates this approach with some direct observations conducted in the area around the city of Milan.

The structure of the text is divided into five sections. The opening paragraph introduces the notion of DCs, highlighting their diverse geographical distribution and localisation factors, categorised according to infrastructure typologies. The second section provides insights into the European and Italian contexts, with a discussion of different case studies and original data collected on the ground. The third part of the article discusses a variety of challenges and opportunities connected with DCs realisation and reported in the literature over the last ten years; they are divided into three major categories: environmental, planning and architectural, and social ones. The fourth paragraph reflects on the relevance of this issue within the domain of territorial planning disciplines, while the final part of the text offers a series of concluding remarks and identifies potential areas for further exploration.

2. Data Center: infrastructures and geographies on the edge between digital and physical

Data Centers are the warehouses and factories of the internet age (Atkins, 2021). They are defined as spaces, either within a building or a building itself, used for the installation and maintenance of computer systems and associated components, including telecommunications and storage systems. They incorporate redundant and backup components, including fuel generators, infrastructure for power supply, data communication connections, environmental controls for server cooling and fire prevention, and various security elements. They can also host offices and meeting rooms, according to their dimensions.

DCs thus plays a pivotal role in ensuring the operation of any information system, functioning as a critical component in maintaining continuous service that support business activities.

DataCenterMap – the first map of this nature to be made available on a global scale for market purposes – currently reports 10,846 DCs, from 170 countries worldwide.

DCs can vary widely and can be categorised in different ways in terms of typology of users and data, size, power requirements, redundancy, and overall structure.

The following categories based on the owner and the type of data are commonly identified by sectorial publications (Hwaiyu Geng, 2015):

- Enterprise DCs, owned by a single organisation (private or public), custom built on the organisation's need and processes, sometimes on the same site of the owner;
- Multi-Tenant or Colocation DCs, which offer spaces and services for data storage and processing to other businesses;
- Hyperscale DCs, designed to support very large-scale IT infrastructure and digital services. These facilities are characterised by their considerable size and high energy consumption. These have been spreading more recently and are usually built by internet 'giants';

- Edge/Micro DCs represent the latest technological developments, responding to the expansion of the Internet of Things (IoT) and the need for analytics and automation (robots, autonomous vehicles, smart grids, etc.). They are characterised by their compact size and proximity to end-users, a feature that facilitates efficient utilisation of resources and reduces energy expenditure.

It is evident that, due to their distinct characteristics, DCs unveil diverse location strategies. Diguet and Lopez (2019) state that flows concentrate in metropolitan areas to minimise the costs associated with optical fibre, whereas storage geographically decentralises into 'operational landscapes' (Brenner, Katsikis, 2020) for lower land and energy costs.

Indeed, colocation DCs are typically based in metropolitan areas (Greenstein, Pan Fang, 2020), where advanced telecommunications infrastructure, such as internet backbones and exchange points[2], absence of seismic risks, fertile economic environment can be found. The central location of these facilities is also linked to the necessity to minimise 'latency', namely the delay before a transfer of data begins following an instruction for its transfer. This aspect is of particular importance for specific applications, such as financial trade.

For other usages, DCs do not necessarily need to be in close proximity to their users. Given their dimensions, hyperscale DCs, which have recently undergone significant centralisation and enhancement, are likely to be situated in suburban and rural regions, as well as in provincial towns. The ideal location for such big facilities is industrial and logistic peripheral areas, which offer large areas, often abandoned or underused, a large amount of electrical power, and good digital connectivity. In the US it is reported that they have reclaimed abandoned areas, such as decommissioned airbases, abandoned nuclear bunkers or shuttered manufacturing plants, (re)defining regional economic imaginaries (Atkins, 2021).

However, due to their monofunctional and introverted nature, they produce very large plots of impenetrable land, often ultra-protected by defensive fences. This has the effect of hindering, rather than improving, the degree of urbanity of the context, contributing to its fragmentation (Diguet and Lopez, 2019).

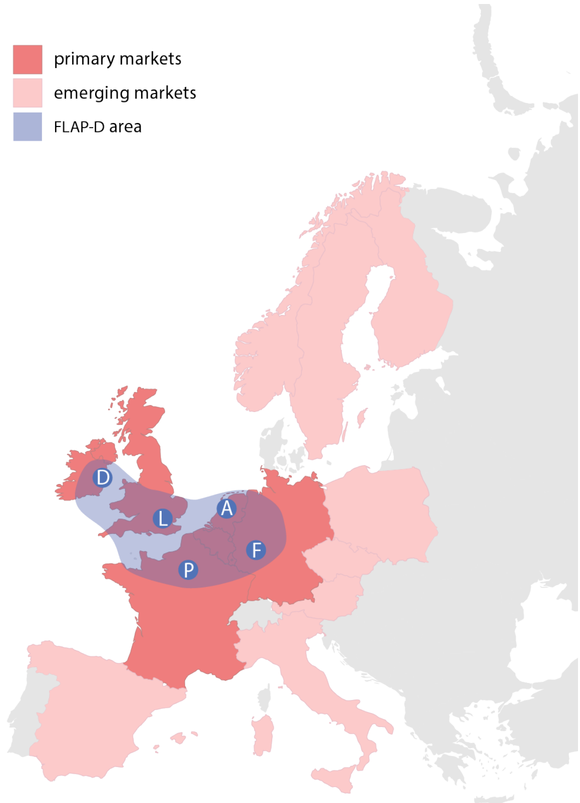
However, it is important to highlight that, in general terms, DCs exhibit distinct and specific localisation criteria. In addition to the previously discussed aspects of infrastructural connection, energy provision and costs, these facilities are often situated in low-risk areas with regard to natural disasters (e.g. earthquakes, floods, fires, etc.) and critical or dangerous facilities. Even if accessible, these facilities are often located far from infrastructural nodes and systems, such as highways and railways (Gazzola et al., 2023).

European geographies of Data Centers: the FLAP-D area and the emerging markets.
Source: author's own elaboration
Fig. 1

A further element that has been documented principally in cases from the US is the proximity to the hydrographic network, which facilitates the utilisation of water for cooling purposes. Likewise, contexts with appropriate levels of humidity and temperature can reduce the use of expansive mechanical and electrical cooling systems. The presence of DCs in uncommon locations, such as undersea levels or within mining sites, is becoming increasingly tested.

3. The European framework and Italy as an emerging market

In Europe, the primary DCs scenario developed within the last 20 years around the 'FLAP-D' zone, which comprises the metropolitan areas of the cities of Frankfurt (Germany), London (United Kingdom), Amsterdam (The Netherlands), Paris (France), and Dublin (Ireland). Indeed, the internet network reinforced existing urban hierarchies, the cables being jointed in metropolitan, global cities (Diguet, Lopez, 2019). It is therefore not surprising that the majority of the European literature on this subject focuses on these cities, which experienced the phenomenon before other territories and have already exhibited criticalities, particularly related to energy network efficiency and stability.
After some recent growth reductions, due also to more restrictive legislations, new markets are emerging, including Scandinavian countries for climate reasons, Poland, Spain and Italy in the Southern Europe (CBRE, 2025). Among these, Italy demonstrates certain strengths, including its significant economic sector, its geographical position in the Mediterranean region, and the stability and reliability of its electric infrastructure.
The current absence of official data on the number of DCs hosted in Italy poses a significant challenge in determining the extent of this phenomenon. The estimation derived from diverse sources can exhibit significant variation, attributable to the different methodologies employed. The Italian Osservatorio Data Center of the School of Management at Politecnico di Milano has indicated 202 facilities (2026), whereas in 2025 the TEHA Group for A2A company counted 168. In addition, DataCenterMap states in 2026 that Italy is home to 209 data centres, including also those that are planned and under construction. The actual number then ranges between 170-200 DCs.
It is important to acknowledge that, despite the existence of data concerning the nominal power of DCs (Osservatorio DC reports in 2026 609 MW at national level),, there is an absence of official statistics regarding their actual electricity consumption. Terna, the Italian transmission system operator, does not collect or publish data on electricity consumption by DC and private operators generally state that actual consumption is lower than nominal power. Recent estimates by energy providers

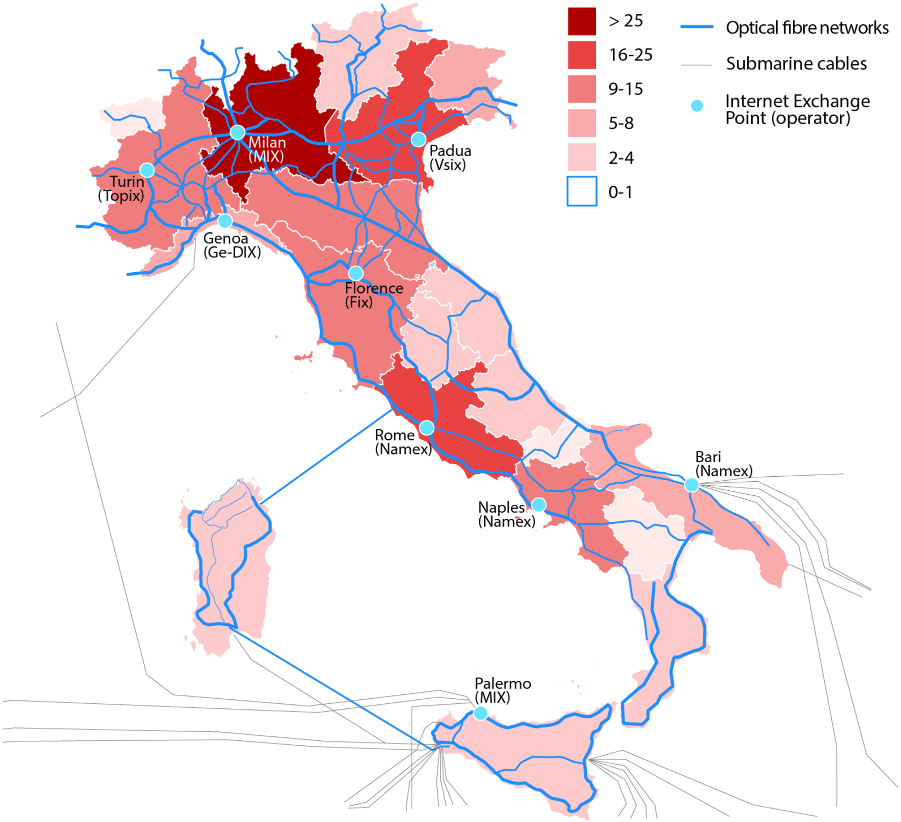


indicate that current national consumption by DCs is approximately 570 MW_{IT}, corresponding to about 3.5 to 5.8 TWh annually. This account for approximately 2% of total national electricity demand[3], a contribution that is predicted to rise between 7% and 13% by 2035 (A2A S.p.a., TEHA Group S.p.a., 2025).

The primary centralities are Milan and Rome. The metropolitan area of Milan and, more generally, the Lombardy region are experiencing an exponential growth of these infrastructures. As of December 2025, the Lombardy region hosts around 50 facilities. It significantly surpasses the number of Data Centers in the neighbouring regions of Northern Italy. The metropolitan city of Milan, which comprises 133 municipalities and a population of about 3 million spread over an area of 1,575 square kilometres, currently hosts 33 DCs, within 32 municipalities. Osservatorio DC (2026) reports that Milan area gathers 414 MW, representing 68% of the whole national capacity.

In order to comprehend the magnitude of the development of the sector, it is useful to consider some data offered by the Osservatorio Data Center (2026), a research institute of the Politecnico di Milano dedicated to this field, which collects data directly from the operators. It is estimated that € 7,5 billion has already been invested in the establishment and activation of Data Centers in Italy during the years 2023 and 2025.

The three-year period 2026-2028 promises to be rich and dynamic with a potential value of around 25 billion. Furthermore, looking at 110



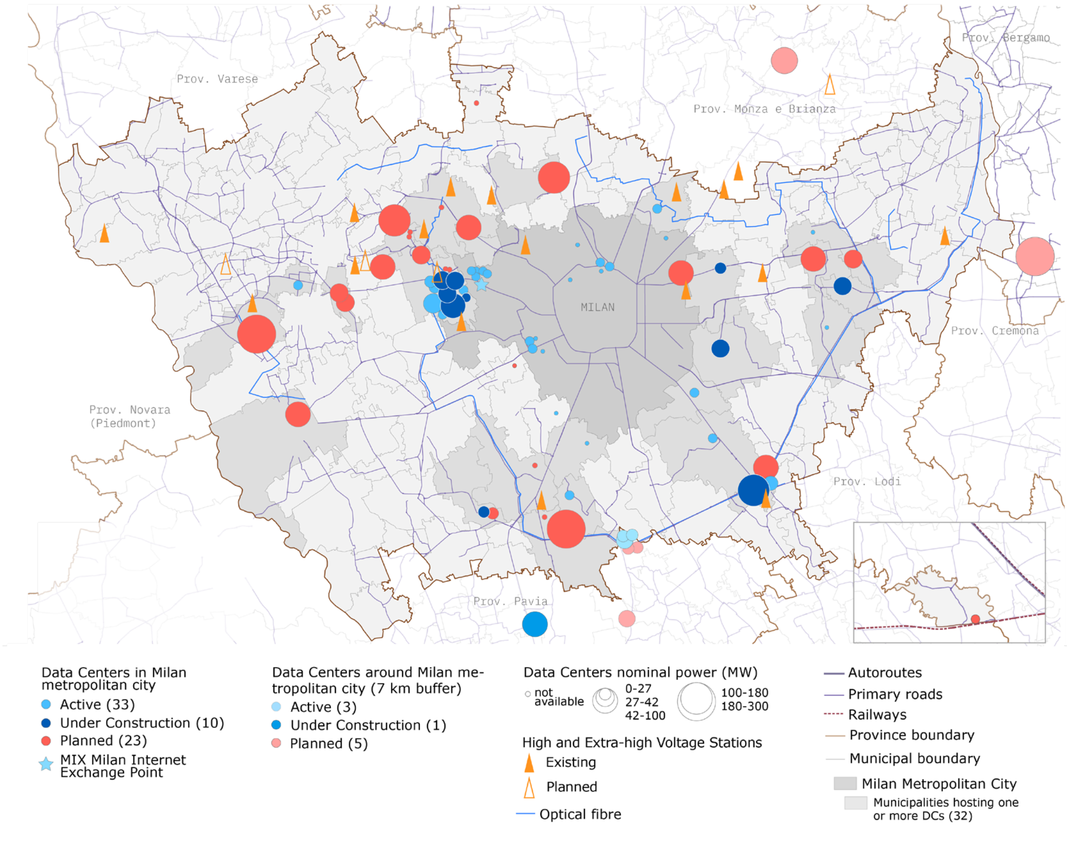
Existing and planned data centers (until 2028) in Italy, classified by region, alongside other digital infrastructures

Source: author's own elaboration on data from datacentermap.com for the number of data centers by region; bbmaps.itu.int for optical fibre networks and submarine cables; and MIMIT (2025) for internet exchange point location

Fig. 2

billion potential investments in DCs across Europe, 23% of them would be concentrated in the Milan area.

This will result in the realisation of many new buildings. According to our research, in the metropolitan area of Milan, a total of 33 new DCs have been announced, of which 10 are currently under construction. According to the data declared in official procedures, these new Data Centers have an 'average size' at least three times larger and four-to-five times more powerful than the existing ones. This phenomenon can be attributed to the spatial effects of the increasing development of two types of DCs: the Campus DCs, defined as large clusters of DCs; and the high-power DCs, characterised by a nominal IT energy power that exceeds 10 MW and necessitate connection to high-voltage infrastructure. The majority of this second category, approximately 70%, are situated in the vicinity of Milan, thereby giving rise to significant concerns related to energy provision (Osservatorio DC, 2025).



Data centers in the Milan metropolitan area.

Source: author's own elaboration on primary data regarding the location and nominal power of DCs; Città metropolitana di Milano for the optical fibre network; OpenStreetMap for electrical stations.
Fig. 3

In the metropolitan area of Milan, Data Centers are mainly located in small and medium-sized municipalities around the capital city, where emerging concentrations are observed. To illustrate this point, it can be useful to consider the municipality of Settimo Milanese – a population of 20,000 inhabiting an area of 10 sq.km. in the Western part of Milan – which was the first to host such facilities in 2013. The site currently houses five different operators, including Big Tech companies, managing approximately nine distinct DCs, which occupy a former telecommunications compound spanning approximately 40 hectares. A concentration in the north-west of the metropolitan area is indeed observed, primarily due to the presence of numerous high-voltage electrical stations and the location of the Milan Internet Exchange Point (MIX). The MIX is one of the largest Internet Exchange Points (IXPs) in Italy and Southern Europe, where a multitude of networks – including internet providers, major websites, and cloud companies – connect their cables and exchange data directly with each other.

The territorial concentration of DCs raises significant concerns, not least with regard to the strong pressure on the local energy system and the unsustainable model of development, but also with respect to the accumulated – and often underestimated – environmental impacts they engender at a local level.

4. Territorial impacts of Data Centers: a literature review

The existing overall situation, as briefly described above, gives rise to complex and inadequately regulated new landscapes in Italy and other European countries.

These issues are beginning to be examined and discussed by professionals and scholars in different relevant fields. However, to date, the approach to DCs has been sectorial, being confined for a long time to engineering and computer science, with a particular attention to new technologies. Conversely, social sciences have scarcely explored the broader socio-territorial dimensions of DCs. A growing body of literature has addressed the political characteristics and impacts of new forms of capitalism. These include the emergence of the concept of platform capitalism (Srnicek, 2017), which highlights the centrality of data in the digital platform economy (Xue et al. 2020), and the intertwined processes of value extraction, finance, and logistics that considers land as a primary asset (Mezzadra, Nielsen, 2019). In this context, digital platforms have been compared to traditional infrastructures, such as railways, as they are now essential facilities that are also managed in a similar monopolistic way (Carr et al., 2022). In fact, the incredible rise of the platform economy has been accompanied by the rapid development of large digital companies that provide essential, everyday services and that effectively act as key actors in shaping development processes (Barns 2020; Mahmoudi et al., 2020; Carr, Hesse, 2022), through top-down and mostly opaque processes.

In more recent times, some geographers began to focus on the materiality of digital infrastructures, seeking to uncover the physical foundations of the 'cloud' (Amoore, 2018; Pickren, 2018), as well as their relationships with territorial context (Furlong, 2021; Turnbull et al., 2023). Nevertheless, there is a scarcity of studies that adopt an explicitly urban planning approach, investigating environmental impacts within the framework of territorial administrative dynamics and long-term territorial governance policies (Diguet et al., 2024; Bast et al., 2022; Carr et al., 2022; Monstadt, Saltzman, 2025).

The present study aims to address this gap by integrating insights from multiple academic disciplines and relating them to the territorial dimension, with a specific focus on how the growing body of scientific evidence on DCs' impacts can be mobilised to inform and improve spatial planning regulations.

In consideration of the recentness of the topic, and the rapid advancements occurring within the digital and technological sector, a review of literature published, and regulations discussed in the last ten years has been undertaken. A range of territorial challenges have been identified:

- the environmental issues, which are principally associated with the utilisation of electric energy;
- water consumption, emissions and air pollution, urban heat islands and waste heat reuse, noise, technological waste, ecological networks and biodiversity detriment;
- the geographical and planning ones, pertaining mainly to localisation, land consumption, the reuse of brownfields and heat, as well as reflections about the impact of private operators on regional and local governance systems;
- architecture-related aspects, such as neglected design, lack of relationship with the landscape, short obsolescence of technological systems and buildings;
- a number of additional issues are addressed, encompassing a variety of domains, including the labour market, the effects on real estate, and the health impacts for workers and local citizens, amongst others.

It is important to acknowledge that a significant body of literature originates from and is associated with the US context, which differs considerably from the European context, particularly with regard to the extent of the phenomenon of DC's presence and diffusion. Nevertheless, this allows us to examine certain forms of effects and impacts that might be considered 'extreme', and that may therefore highlight critical points to be taken into consideration for the future development of the DC sector in Europe and Italy.

4.1 Environmental impacts

A substantial body of recent literature has drawn attention to several issues associated with the environmental impact of DCs. Our review reveals three principal issues, namely electricity consumption, water consumption and emissions (Siddik et al., 2021).

The primary issue is indisputably the most significant in terms of scientific evidence and field studies: it is estimated that Data Centers currently consume between 1% and 3% of global electricity (International Energy Agency, 2025). According to the EU, in 2018 they accounted for 2.7% of electricity demand in the EU-28 (Directive 2023/1791), with forecasts of an increase due to the announced advent of AI. It is evident that, regardless of the calculation models and growth scenarios considered – which are sensitive to behavioural usage trends and technological advancements –, a rise in energy consumption by 2030 is inevitable. This increase is projected to range from approximately 300TWh to 900TWh (Koot, Wijnhoven, 2021) or even up to 1.600TWh by

2035 (A2A S.p.a., TEHA Group S.p.a., 2025). Despite the fact that new hyperscale DCs are subjected to more stringent environmental standards and demonstrate greater efficiency in terms of energy consumption, due to economies of scale and standardisation, high electric energy consumption remains a 'key theme' in the reduction of emissions due to fossil fuels and the planning of the capacity of national grids, with possible emerging processes of competition between urban uses (Thangam et al., 2024). In recent years, indeed, the capacity of national electric networks has been a subject of considerable debate due to the unprecedented increase in investment in the DC sector. In the opinion of stakeholders (CBRE, 2024), the availability of electric power is the primary factor influencing the growth of DCs on a global scale. In Italy, Terna (2025), the company that manages the national electric grid, has defined DCs as 'a challenge' for planning new investments for the modernisation of the network. Secondly, the increase in electric energy usage poses the issue of the sources. Ireland is a 'borderline case' that highlights great potential problems. In a context of 22% of national electrical energy being consumed by DCs in 2023, it has been demonstrated (Daly, 2024) that between 2016 and 2022 production from renewable sources did not increase, even if DCs bought green energy which is predominantly produced from wind. The total amount of fossil-fuel energy consumed in Ireland remained unchanged, thus jeopardising the State's commitment to reduce carbon emissions by 2030. At this juncture, there is no evidence to suggest that DCs have functioned as a catalyst for augmenting energy production from renewable sources (Bashroush et al., 2020).

However, a review of international case studies reveals that several European countries have implemented restrictions on new DCs with regard to plant efficiency and obligations on energy production from other renewable sources (France, Germany, the Netherlands, Ireland), as required by the EU Energy Efficiency Directive (not yet transposed by Italy). In Germany, for instance, the 'Energy Efficiency Act' (2023) now permits a PUE (Power Usage Effectiveness, which is calculated as a ratio of the total energy consumed by the entire facility to the energy used by the actual IT equipment) between 1.5 and 1.3, which will shift to 1.2 for new DCs constructed from 2026. In addition, DCs are obligated to utilise 50% renewable energy from 2024, increasing to 100% from 2027. In Ireland, a recent proposal of the 'National Commission for Regulation of Utilities' (2025) suggests the production and storage of energy to DCs. In the United States, prominent companies such as Microsoft and Facebook have already initiated micro-grid programmes. This suggests a commitment to energy autonomy but also poses questions regarding the ownership of energy.

Issues pertaining to water and emissions are less extensively explored in the extant literature, yet they are no less impactful. It is particularly evident that DCs constructed 20-15 years ago typically utilise water in significant quantities for cooling equipment, whereas the most recent ones often adopt alternative solutions. In addition to direct consumption, DCs can also utilise water for the production of electricity, as observed at the Aruba Campus in the province of Bergamo, Italy. Mytton (2021) estimated that the daily water consumption in the US is approximately 1.7 million litres. Despite constituting a mere 0.13% of total water consumption, he highlights the high concentration of withdrawals in specific regions, along with the fact that 57% of this is drinking water. This has resulted in significant challenges across large parts of the country, particularly in areas most affected by drought, where land prices are low and attract DCs. In Italy, the issue has received limited scholarly attention, largely because the most recent DCs generally use less or no water, as they have liquid cooling or water recirculation systems. In the US, some DCs have also begun to utilise greywater for cooling purposes. In any event, the fact that legislation adopts a specific indicator (WUE – water use effectiveness) and that some of the 'big Tech' companies, such as Microsoft and Digital Realty, are working on innovative solutions for reducing their water consumption demonstrates the persisting urgency of the issue.

A substantial body of research has been dedicated to the study of CO^2 emissions (Ewim et al., 2023). Direct emissions comprise greenhouse gases and pollutants resulting from the operation of DCs. Literature identifies diverse sources, but the most problematic one is related to the presence of a big number of diesel-fuelled back-up generators. Consequently, the subjection of DCs to Environmental Impact Assessment (EIA) is currently only due to the presence of these elements. Despite their rarer utilisation for emergency situations, these devices must undergo monthly testing, thus emitting damaging quantities of NOx (nitrogen oxides) (Nelson, 2022). Furthermore, DCs are equipped with fuel tanks, which pose a significant risk in the event of a leak or explosion. The question of depolluting sites after use is also likely to be raised in future (Diguet, Lopez, 2019).

It is evident that public awareness of the environmental impacts of DCs has increased in recent years, and this has also become a significant driver of social protest. A limited but growing body of research has begun to document this phenomenon in the United States (Ngata et al., 2025). For instance, certain studies have examined community mobilisations such as the Dobson Noise Coalition, which has focused on the health impacts of DC-related pollution in the city of Chandler, Arizona (Monserrate, 2022). In recent times, communities in Memphis, Tennessee, have organised themselves in opposition to the data centre of X company. They argue that the facility poses a threat to local energy and water systems in an area already designated as a 'sacrifice zone' (Koller, 2025). This concept (Juskus, 2023) in its broadest definition delineates an area "systematically impacted, socio-economically and ecologically, by the negative effects of resource extraction or transformation, while the benefits of these activities largely accrue elsewhere" (Pellizzoni, 2025, translated by the authors); it may therefore provide a useful analytical lens for examining marginal territories hosting clusters of DCs, and disproportionately bearing their impacts. In a similar way, Johnson (2019) suggests that the distribution of such infrastructures highlights possible digital inequalities between 'serving' and 'served' territories. He highlights the fact that good digital connectivity can coexist with marginality when places are exploited for their resources.

To overcome or limit the environmental issues, a number of studies and regulations have explored and proposed guidelines related to the concept of 'green DCs', addressing technical innovations, such as the use or production of renewable energy and the utilisation of liquids for cooling systems, thereby enhancing the efficiency of buildings (Manganelli et al., 2021; Liang et al., 2024).

The European Commission has assumed responsibility for the subject in 2008, when *The Code of Conduct on Data Centres* was published. It is intended to encourage the operators and stakeholders of DCs economy to implement good practices with a view to reduce their environmental and economic impact.

Moreover, reflections on 'urban metabolism' and the transformation of DCs into opportunities for the cities have been initiated and innovative solutions have been tested in certain contexts (Huang et al., 2020). A noteworthy subject is the reuse of heat generated by DCs that can be recycled through low and ultra-low district heating networks in surrounding urban areas for residential or industrial purposes. This approach has the potential to reduce local heat islands – an effect that is absent in the literature, but that is common to similar urban areas, such as the industrial and commercial ones – and the overall energy consumption of cities, thereby contributing to adaptation to climate change. Despite the emergence of numerous regulations in European countries on the topic – in Germany a minimum share of 20% of waste heat is required from 2028 – and some Italian[4] (A2A S.p.a., TEHA Group S.p.a., 2025) and Dutch initiatives that call for the reuse of heat, limitations can arise and must be considered (Monstadt, Saltzman, 2025). Firstly, it is an essential prerequisite that a district heating network is already in place, and the energy company participate in the governance process. Eventually, it is possible to envisage the possibility of reusing the heat in the future, waiting for the realisation of the network, which, however, can take some years and may be far away from DCs. Secondly, the waste heat from DCs has a relatively low temperature for district heating, necessitating an increase to approximately 85 °C, with additional electricity use. Consequently, some scholars have proposed the construction of 'Organic Data Centers', which entail the integration of a DC and a greenhouse, situated in proximity (Karnama et al., 2019).

4.2 Geographical, planning and architectural issues

There are other aspects emerging from the literature that merit attention and in-depth research, particularly in the field of spatial studies: neglected architecture with no dialogue with the surrounding context; technical planning issue related to zoning and tax revenues; land consumption for DCs built on greenfield instead of brownfield; fast obsolescence.

More in general, as stated by Diguet and Lopez (2019, p. 7), "questions on the urban integration and architectural potentialities of these objects have been little analyzed, even underestimated, in the same way as a more eco-systemic reflection that would make it possible to better insert data centers into local energy systems". In their study on the US and Ile-de-France area, the two scholars present numerous case studies of DC's interactions with the environment in which they are embedded, in their architectural and urban dimensions, in relation to energy, economic and governance issues.

From an architectural perspective, the 'shoebox' model is discussed, whereby the physical container does not visually indicate the strategic significance of the content, thus contributing to discretion and security. As demonstrated by the presentation of US cases, including that of Facebook, a variety of possibilities emerge for the integration of offices, meeting rooms, and other services (e.g., gym, restaurant) within DCs, both in inner cities and on outskirts. In Italy, the Aruba Campus is a notable example of a corporate initiative that has also resulted in the construction of an auditorium.

With regard to the issue of land consumption, in the work by Diguet and Lopez (2019) reference is made to a shared concern relating to the design of parking lots. Also in Milan, a significant number of operators reported to having requested a reduction in urban standard services, attributable to the limited number of employees. Actually, these areas can be used more effectively for outdoor space and planted surfaces, with the aim to reduce heat island effect and integrate the DC into the landscape.

In addition to parking lots, the more general conversion of agricultural areas into DCs has also resulted in significant land consumption. Despite the prevalence of interventions developed on brownfield sites, this issue persists and is anticipated to worsen in the absence of adequate legislative measures.

The increasing prevalence of Campus and Hyperscale Data Centers necessitates the utilisation of substantial spatial dimensions, which are not easily available in vacant areas, considering also the requisites associated with the location of these facilities, a topic that has been previously explored. The absence of studies on this issue in the literature is striking, particularly in the context of the United States. However, some Italian scholars have begun to identify potential risks to soil integrity and the irrelevance of environmental guidelines (Pileri, 2025). In order to overcome this deficit, our research in the metropolitan area of Milan is collecting data about DCs dimensions and land consumption. A consideration of the total number of DCs under contruction or planned reveals that 39% of these are or will be located in greenfield sites, but they are covering 54% of the total land occupied by DCs, while the remaining interventions are situated in former industrial areas (46% of the total surface).

The Italian Institute for Environmental Protection (ISPRA) has cited DCs as a contributing factor to land consumption for the first time in its 2025 Annual Report (SNPA, 2025). Despite their limited impact in comparison to that of logistics, new DCs accounted for 37 hectares of land loss in 2024 alone (with the majority of interventions occurring in the Lombardy region), and it is anticipated that this figure will increase steadily through to 2030.

Two ancillary reflections are then worthy of mention. Firstly, due to the uncertainty surrounding technological development, particularly with regard to AI, there is a risk of overestimating the size of these facilities. This could result in the creation of DCs that will not be utilised to their full capacity or will house 'comatose' servers that persist in consuming electricity and other resources without performing any useful work (Herrlin, 2024). It is evident that speculation phenomena have already manifested in the area of study, coinciding also with an exponential demand for electric connection[5]. Secondly, Data Centers are not isolated entities. The buildings are linked to existing infrastructures, particularly energy and telecommunication networks. The necessary cable systems, financed and constructed by the operators, connect the DCs to the nearest electric substation. These can be extensive in size, having a significant impact on numerous municipalities and resulting in additional land consumption.

About the issue of obsolescence, there is a lack of consensus regarding estimations. According to research undertaken by International Data Corporation (IDC), the average age of the equipment installed in a DC is 9 years. Gartner, another research company, has stated that DCs which have been in existence for a period of more than seven years are outdated. Undeniably, the escalating volume of data is a key factor driving the imperative for Data Centers to modernise. The theme pertains to 'legacy' DCs that are already in need of refurbishment and is intrinsically linked to the pressing issue of digital waste, which is expected to occur within the next 15-20 years, as well as to (present and future) demands for realisation of new DCs, replacing the older ones.

The extant literature does not address the topic of building obsolescence or decommissioning (even if a specific plan is required by the Italian Ministry for the Environment and Energy Security), and examples of DCs reuse are not available at the present time. However, situations of rapid abandonment in Canada have been shown to engender a risk of producing 'digital ruins' due to rapidly changing corporate strategies, markets, politics, and technological obsolescence (Brodie, Velkova, 2021). In certain instances, these phenomena manifest as abandoned infrastructure. At other times, they may assume the form of incomplete assemblages, as described by Burrell (2020), or as projects that never gained traction for construction, as posited by Carse and Kneas (2019).

4.3 Social impacts

The potential for job creation and local economic revitalisation, frequently emphasised in public discourses concerning the realisation of Data Centers, remains ambiguous. DCs generate a limited number of employment opportunities, and the sector is constantly stressed about its future. On the one hand, there is a shortage of technical-skilled workers; on the other hand, automation will be able to replace many employees at all levels (Mayer, Velkova, 2023). Consequently, even if employment opportunities are abundant and esteemed, they are often accompanied by a concomitant element of insecurity. With regard to the nature of the work, it is important to note that the majority of DC workers are male and white. The nature of the task is such that it is repetitive in nature and has been classified as 'stand-by' (Taylor, 2021) in the sense that workers are required to engage in constant monitoring, yet the necessity for intervention is minimal. It is imperative that they be prepared to be available. The general effect is that of an empty space, where workers feel lonely and isolated.

Jones et al. (2013, p. 111) reported that the construction of a DC can generate a significant economic benefit to the local economy during the construction phase. They stated that "a 20,000 square metre Data Center might typically generate 100 permanent jobs, with 50% being directly involved in management and operation of the Data Center facility and the other 50% being in ancillary support jobs". Ongoing maintenance and operations roles, albeit limited in number, necessitate specialised competencies, thus creating opportunities for highly trained professionals. Furthermore, once localised, DCs offer the possibility of financing local training and vocational activities in the field of digital economy, as well as social and recreational events.

Despite the scarcity of direct employment opportunities, public discourses state that DCs may also assume a pivotal function in the retention and support of existing companies, in addition to the attraction of new economic activities. Whilst the impact on local and regional businesses appears to be marginal, the presence of DCs can stimulate the digital market on a national scale, thereby catalysing substantial investments. As stated in the A2A report (2025), the Italian data economy, which is associated with the growth of digital data, already accounted for 2.8% of the national GDP (€60.6 billion) in 2024. It is anticipated that this sector will continue to expand in subsequent years, facilitated by the strategic presence of DCs within the national territory. Furthermore, it has been argued that DCs' development in Italy has the potential to contribute up to 6% per year to GDP growth, with the creation of 77,000 jobs by 2035.

Contrasting with these considerations limited to macro socioeconomic opportunities, the work of Libertson, Velkova and Palm (2021) on Sweden proposed to insert DCs development within a notion of 'energy gentrification', highlighting obstacles and possible conflicts in the local use of electric energy. They reported that big tech DCs have been attracted to Sweden due to the favourable conditions, which include low costs of (renewable) energy. However, these companies have also created problems due to a lack of grid capacity in some regions, with the result that several local industrial facilities and infrastructural projects have been put on hold. Furthermore, "in its most extreme form, energy gentrification can also affect the energy supply of proximate municipalities and other communities" (*ibidem*, p. 157). The authors thus questioned the prioritisation of energy demands and underlined the underestimation of DCs impacts in energy and spatial planning. These processes unveil unequal power relations and demonstrate a global interest (DCs) that overrules the local economy, marginalising some actors from decision-making. As will be discussed in the following section, these issues are not confined to energy; territorial planning is also implicated.

5. Data Centers and the territory: a relevant issue

As demonstrated in the existing literature and also revealed by the primary data collected within the 'ProdAction' research project and related to the metropolitan area of Milan, challenges related to the development of Data Centers are manifold and strongly interconnected. Consequently, small local municipalities, such as those operating within the metropolitan area surrounding Milan, encounter challenges in addressing these issues due to a general scarcity of the requisite technical and sectorial preparation, expertise, and human resources.

Furthermore, due to their considerable energy demands and dimensions, DCs represent a significant source of revenue for energy grids and regional economies, as well as local tax income. Consequently, several governments have offered incentives to attract them, including economic concessions and infrastructural accommodations (Brodie, Velkova, 2021). In the context of the prevailing scarcity of public resources at the local level, it is challenging to decline the opportunity presented by developers and operators with substantial financial resources. These private actors frequently possess the capacity to revitalise an abandoned area that has been left unused for decades, or to provide significant compensations, whether environmental or social character.

It is thus evident that a distinctly asymmetrical dynamic is established with operators on both a technical and a negotiating level. Consequently, private actors assume a dominant role in the development of DCs, both with regard to the selection of site locations and the formulation of technical and contractual proposals.

Present challenges are not only due to the recent emergence of DCs, but also to a general lack of transparency in the field, due to its secrecy, that make difficult to accurately determining the location, size, energy consumption and water usage of DCs (Carr et al. 2022; Monstadt, Saltzman, 2025). This issue has been recently addressed by the EU Directive 2023/1791, which imposes data reporting obligations to DCs operators on the Commission, and more specifically by Commission Delegated Regulation (EU) 2024/1364, which has been in force and legally binding since September 2024. Operators of larger DCs are obliged to report sustainability key performance indicators (KPIs). However, the European database remains inaccessible to the public at present.

These conditions result in the challenging definition of planning tools to regulate and govern DC spatial development at different scales. Whilst in Europe, the countries in which DCs were initially established have since become more restrictive, with some even imposing moratoria on DC construction (Monstadt, Saltzman, 2025), the absence of clear national or regional laws in Italy provides neither public nor private actors with the necessary elements of certainty. This, in turn, gives rise to problems of competition among territories. Nevertheless, the subject is currently the focus of political debate.

In 2024, the Ministry for the Environment and Energy Security and the Lombardy Region established guidelines on environmental assessment and application procedures, formulating preliminary regulations that, however, lacked prescriptive nature. In the same year, a total of four draft laws were submitted to the Italian government by various political parties. The documents have been consolidated into a single proposal, which is currently under review. A number of territorial and spatial issues have been identified, including land consumption, brownfield reuse, energy efficiency, renewable energy production and territorial equalisation. However, the primary focus remains on the simplification of procedures with a view to attracting investment. In a more explicit way, the Italian Ministry of Enterprises and Made in Italy has published a national Strategy for DCs attraction (2025) that suggests a more homogenous diffusion of these facilities throughout the country for increasing the resilience of energy grids and the latency of services. Despite the current limited presence of DCs in Southern regions, they exhibit notable technological and infrastructural elements, including the presence of optical fibres, the recent diffusion of exchange points, and the arrival of submarine cables. Consequently, they have the potential to function as a digital gateway for the entire Mediterranean region.

6. Final considerations for further research

All the available data indicates a global and national trend of significant development of Data Centers in the very near future. As reported by the paper, this phenomenon is unprecedented in the field of territorial planning, particularly in Italy, due to the nature of the infrastructure involved, its respective needs and impacts, the rapidity of realisations, the quantity of capital involved, and the various actors engaged. Consequently, the digital and data economy necessitates careful consideration within the territorial field to address all the different challenges and opportunities posed.

A crucial element related to planning techniques is the explicit identification of Data Centers. Their hybrid nature poses challenges in terms of their classification within traditional land use categories (Jones et al., 2013). Should their impacts be ascribed to industrial activities, however, when considered in the context of their functions, a stronger affiliation emerges with logistics (stock) and the tertiary sector. In Italy, private actors and associations – in particular the Italian Association of Data Centers (IDA) – have called for the necessity to recognise DCs as a specific economic activity, thus avoiding ambiguity. However, the absence of clear legislation at present means that each municipality can decide on a subject that is crucial for calculating urbanisation and building costs, compensations, and tax revenues. This poses issues of local competitiveness, which can be addressed by defining specific locations for these facilities. In this way it would be possible to avoid competition with other land uses and to attract investments, as some FLAP-D cities have recently shown. Nevertheless, this decision may give rise to speculation phenomena and necessitate a re-evaluation of territorial equalisation to ensure equitable distribution of benefits. The issue of how to define DCs localisation, inserting them into broader territorial and energy strategies, is thus of pivotal importance.

On these two issues, the Metropolitan City of Milan has set some directions for local municipalities through the *Thematic Territorial Strategy for the Innovation of Production, Service and Distribution Spaces* (May 2025), a document that is part of the *Strategic Metropolitan Plan*. It identifies DCs as infrastructures of tertiary nature and supralocal relevance, thus calling for the implementation of environmental evaluation (VAS) procedures and concertation. The Strategy also defines the criteria for localisation and, through two specific maps, identifies areas of exclusion and attention according to environmental and landscape components, as well as elements for the definition of areas for suitable location, following principles of functional integration and territorial regeneration. Nevertheless, the implementation of this innovative experimental normative framework has been hindered by the ongoing debate on a dedicated law at the regional level, which is shifting towards industrial land use.

The research project 'ProdAction', which provided the foundation for the present study, seeks to offer policy proposals that are grounded in scientific evidence and informed by a comprehensive collaborative process involving multiple stakeholders. Stakeholder engagement, particularly with public bodies, has highlighted the necessity for specific laws that include prescriptive elements, particularly concerning land and energy consumption. These laws should be complemented by a series of incentives to promote the sustainability and territorial integration of DCs, envisaging streamlined procedures.

Whilst this is not the primary focus of the present paper, some areas of interventions have been identified and will be further developed as part of the research. We will provide policymakers with recommendations related to defining specific requisites for energy consumption and efficiency at a building level; the reuse of brownfields; the identification of environmental compensation measures, as well as more general planning rules for DCs localisation, related to specific zoning areas but also to the opportunities of creating urban cycles.

The political and administrative dynamism, in conjunction with the rapid market-driven processes of development observed, suggests that the case of Milan and the Lombardy region may serve as a testbed for innovative and replicable territorial planning strategies and instruments for a more sustainable and integrated approach to Data Centers development.

Notes

[1] It is one of the pilot research projects funded by the Competence Center for Anti-fragile Territories of the Department of Architecture and Urban Studies of the Politecnico di Milano. The Centre explores the skills and tools necessary to support public administrations in managing emerging challenges in the relationship between space and society. It aims to contribute to the activation of antifragile resources and sustainability in the territories. For more information, see the website https://craft.dastu.polimi.it/en (last visited December 2025).

[2] Internet exchange points are physical locations that facilitate the exchange of internet traffic between different networks and internet service providers. These central hubs enable efficient and cost-effective data exchange, reducing latency and improving network performance. They also foster network resilience, enhancing local and regional internet connectivity, and enabling the growth of digital ecosystems by facilitating the exchange of large volumes of data at high speeds.

[3] These data were collected during the participation of a webinar titled 'Data center e rinnovabili' [Data center and renewable energies] held on the 10th December 2025 by Elettricità Futura, the Italian leading association of the electricity industry. Further details can be found on the webpage: https://www.elettricitafutura.it/Media/News/Technology-Watch-data-Center-e-rinnovabili-infrastrutture-digitali-per-la-transizione-energetica_6819.html (last access December 2025).

[4] According to calculations performed by TEHA for A2A (2025), the reuse of heat from data centers located in proximity to existing or planned district heating networks has the potential to reach 9.5 TWh per year. This is equivalent to the heating requirements of 800,000 Italian households, of which over 530,000 are in the Milan metropolitan area alone. It has been calculated that this would result in potential savings of up to 2 million tonnes of CO_2 per year at full operational capacity, being equivalent to a 5% reduction in emissions from the residential sector.

[5] During a conference in May 2025, Terna – the Italian transmission system operator – disclosed that it had received requests for approximately 44 GW of power, which exceeds the European nominal IT energy power. However, it is anticipated that only a limited proportion (around 1 GW) of these requests will be converted into actual DCs. In accordance with Terna's obligation to ensure grid connectivity, the acceptance of such unrealistic requests hinders the quantification of demand and the effective planning of supply.

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