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DATA CENTER GROWTH AND PROPOSALS FOR REGULATION

LESSONS FROM THE PARIS REGION

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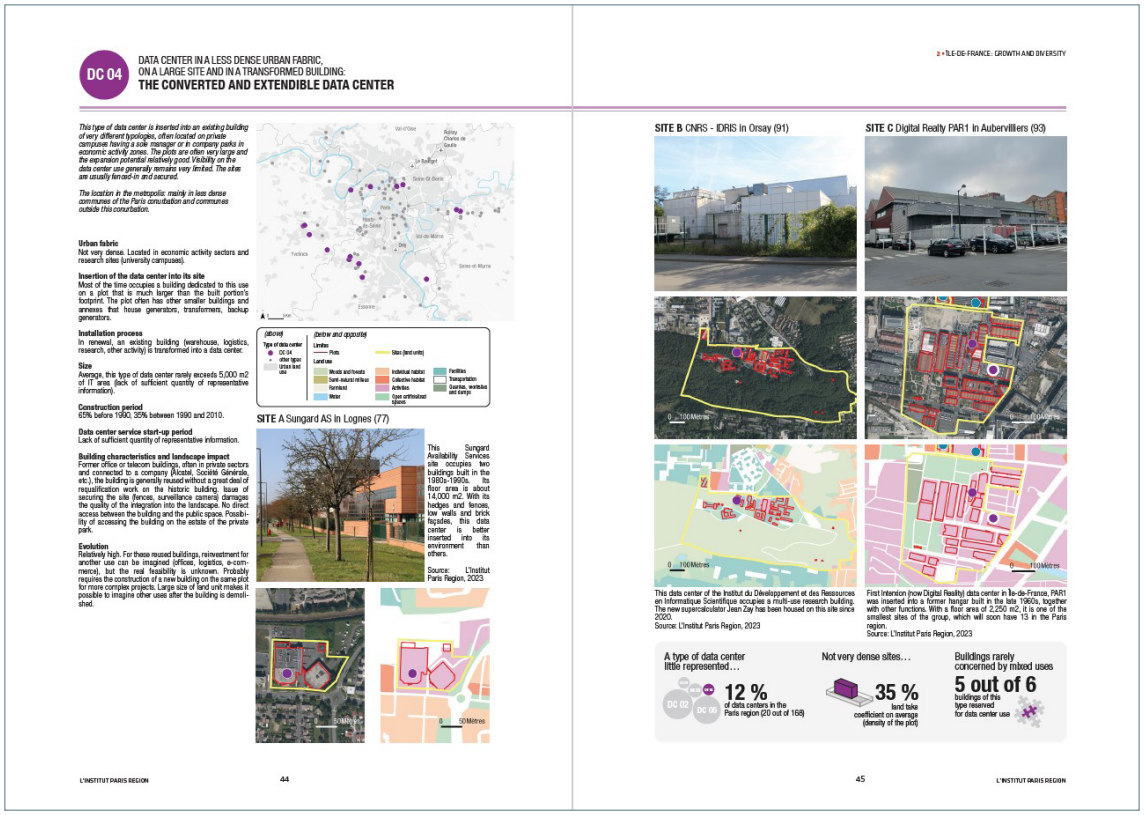
EXECUTIVE SUMMARY

Data centers have become an infrastructure that is consubstantial with digital uses over about the last 15 years, notably boosted by the explosion of virtualization (clouds, platforms). However, they remain almost invisible objects for the general public, and relatively opaque in the eyes of public actors. In Île-de-France, as in other European and world metropolises, data centers have now become a political policy and local debate subject, in liaison with the awareness of the digital's environmental impacts, and the necessary road to be taken toward sobriety.

The spectacular development of the data center market that has been observed since the early 2000s is the result of the digitalization of every human activity (economy, administration, health, education, culture, leisure, etc.). Throughout the world, the number of data centers has been continuously increasing. The Île-de-France region is an attractive territory for hosting data centers in France and one of the most attractive in Europe. Over the last two decades, the development of data centers has accelerated in the region to reach a total number of over 160 in 2023.

In Île-de-France, there is a large variety of host territories, forms, ages and types of data centers.
Source : L'Institut Paris Region, 2023.

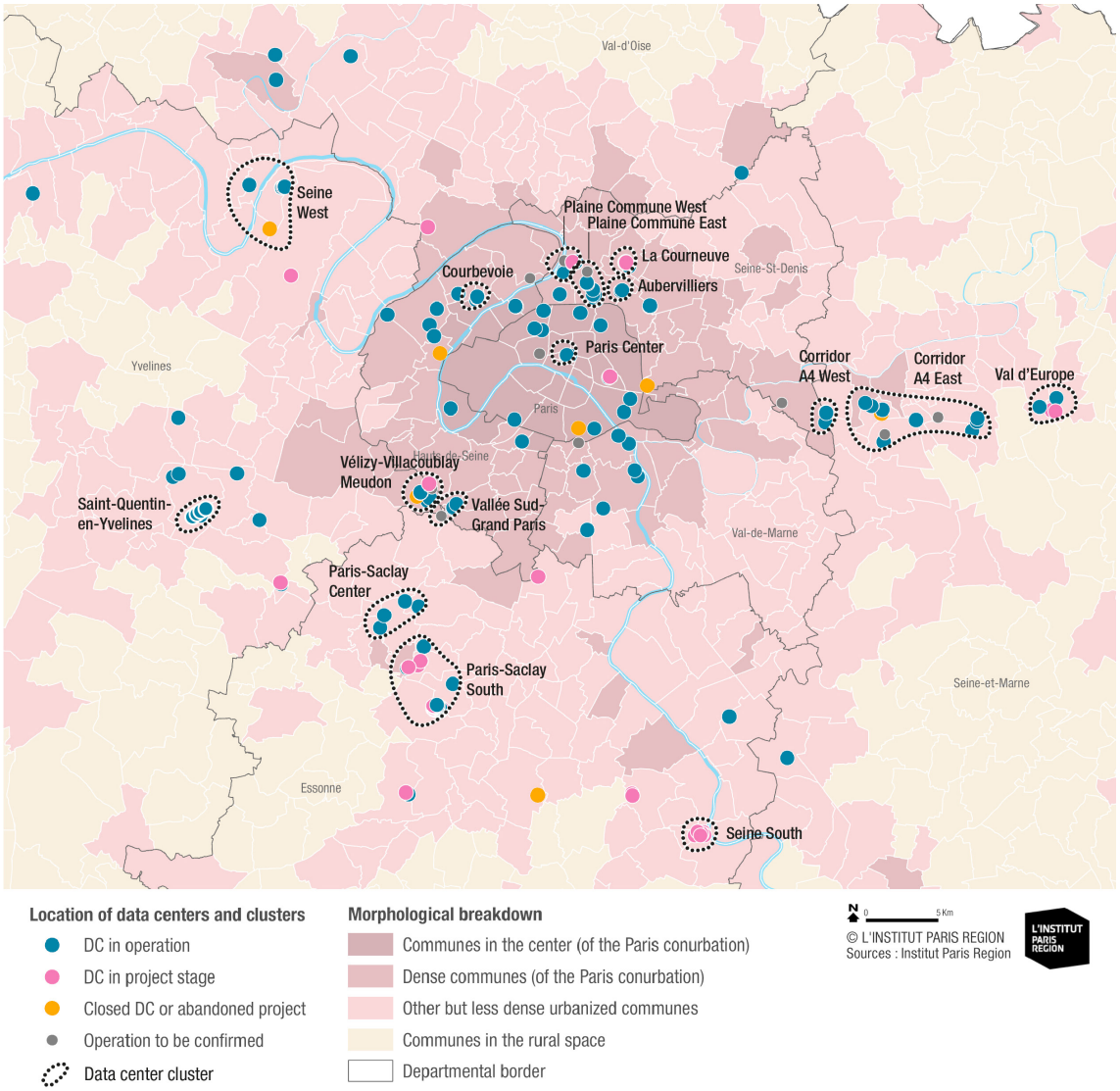
This study makes it possible to better know these infrastructures, which are recent in the history and urbanism of the Paris region. By analyzing all the existing data centers, L'Institut Paris Region has observed a certain number of technical, construction, security and programming characteristics that are shared by the data centers; others distinguishing them as a result of a considerable diversity of sizes, forms, function, technologies and operating modalities. In order to better understand their siting modalities and the resulting spatial impacts, a typology based on exclusively spatial criteria is proposed in Part 2 of this work. Consequently, five types of data centers ("infiltrated data center," "converted data center in an activity zone," "new and optimized data center," "converted and extendible data center" and "new data center on the metropolitan outskirts") have been identified. They are illustrated by concrete examples.



Example of a typical sheet for a "converted and extendible data center" that is one of the 5 types of data centers identified by L'Institut Paris Region in this report. Source : L'Institut Paris Region, 2023.

According to our observations of current development trends, the data center market is tending to accelerate with the risk of even soaring over the next few years, which is confirmed by the projections of the ADEME (French Environmental and Energy Management Agency) and the ARCEP (French Regulatory Authority for Electronic and Postal Communications), as well the knowledge of projects to come by electricity operators and the MRAe d'Île-de-France. Certain types of data centers have developed more heavily than others and in the upcoming years, growth should continue in certain territories of the Paris region and slow down in others. Consequently, requests will probably increase, in number but especially in installed electrical power and floor area, in the territories where favorable local political contexts and large available plots exist in new economic activity sites to host the emerging model of cloud data centers of large dimensions notably operated by Amazon, Microsoft and Google. Requests will also undoubtedly continue where the urbanization potential has still not been reached and in aging company parks and/or abandoned buildings and wasteland. Finally, territories are also concerned in which the local urban planning documents permit such installations and in which there are no particular curbs in terms of electricity or internet network availability. On the other hand, growth should slow down where dense territories and those in full urban transformation are faced with increasingly great real estate development pressure and where there is a need for reducing pollution and/or urban dissections for the population at the same time as improving their living environment (by creating green spaces, public facilities, etc.). This deceleration would also seem to concern the sectors where there is a reticence and/or a local mobilization against land artificialization or in favor of an alternative project in a denser milieu and in sectors where there is local tension on the electricity transmission and distribution networks.

TERRITORIAL BREAKDOWN OF DATA CENTERS



The growth of the data center market in Île-de-France could have a considerable impact on electricity consumption and the robustness of the electricity network, in a context of increasing needs, notably linked to the electrification of mobilities, and uncertainty on production capacities. It will also have repercussions on land in the Paris region (real estate development pressure on already urbanized land) and the dynamics of urban expansion and land artificialization of farmland, even forests, and more broadly on natural resources (including on water and materials). The global impact of risks and pollution produced by data centers on human health remains to be studied (noise for example), but certain aspects are already well-known, such as the risk of fire or the contribution to the overheating of cities (waste heat released into the environment and the urban heat island effect). The consideration of these subjects is therefore not necessary solely for the new projects, but also concerns existing data centers.

The thematic issues that permit public actors to better apprehend these issues linked to this growth of data centers are sketched out in this study. The following issues are discussed:

- **Issue 1:** Land use sobriety and preservation of open ground;
- **Issue 2:** Urban integration;
- **Issue 3:** Prevention of risks and pollution;
- **Issue 4:** Sustainable management of energy;
- **Issue 5:** Sustainable management of other resources.

Sometimes, there are already solutions (technical, spatial, construction, etc.), here and elsewhere, but they often remain little-known due to a lack of knowledge-sharing. In other cases, new ways of doing are still to be invented. Taking these issues and their impact into account is a first step, making it possible, tomorrow, for public and private actors to find responses adapted to each territory. It must not be forgotten that the financial resources of the data center actors and their appetite for innovation are greater than those of other activities. Shouldn't they become a lever to design flagship projects in terms of energy sobriety and efficacy and in water and materials, but also in terms of architectural quality and urban and landscape integration?

Part 4 of this study offers a list of precise proposals, based on the criteria and issues cited above in other parts of the report. The aim of these proposals is to accompany public administrations in the hosting of data centers in Île-de-France, making sure to maximize the positive feedback of their development and minimize the negative impacts. This concerns new installations and existing data centers, on which many improvements on landscape and urban integration and on architectural quality can still be made.

The aim of our proposals is first of all to be discussed with the identified public and parapublic actors to comprise the first core of the "collective of data center public and parapublic actors in Île-de-France," which is one of our principal recommendations. Part 4 of this report also includes a first contribution to the creation of a shared analysis grid of the data center projects between the public and parapublic actors in Île-de-France and that includes stress on the existing regulatory frameworks, environmental procedures, possible supervision tools, and so on. All these elements aim at guiding the collective construction of an optimal data center integration strategy in the different territories of the Paris region.

SUMMARY

INTRODUCTION

Since the publication of the report *The Spatial and Energy Impact of Data Centers on the Territories* for the ADEME in 2019,[1] the reflections on territorial integration, sustainability and regulation frameworks of digital data centers have multiplied. In Île-de-France, as in the regions of Dublin, Amsterdam and Stockholm,[2] in the San Francisco Bay region or now in Marseille, this long little-known infrastructure has become the object of public policies and local debate, at the continuous intersection of digitalization dynamics of societies and economies, just as much as the raised awareness of the digital's environmental impacts, and of the necessary digital sobriety. This study places the emphasis on the situation in the Paris region, with the objective of enlightening the local administrations that host data centers by providing the keys to understanding this technical, energy, architectural and urban object, on this issues set out, on the existing regulatory frameworks, environmental procedures, possible supervision tools, but also, by offering proposals to go further in a collective construction of an optimal integration strategy for data centers in the territories.

A digital infrastructure that serves the territories?

The international consulting firm Arcadis sees France as one of the world's leading locations for siting data centers. Being located in France guarantees a rapid and durable return on investments. It is estimated that the Paris market[3] represents, with 70%, a considerable domestic market share of data centers. The Île-de-France region would therefore be the most attractive territory for hosting data centers in France[4] and one of the most attractive in Europe. Equinix, one of the worldwide leaders of data center operators, has identified Paris within the European market[5] as a metropolitan center that has experienced the fastest growth and as a major ecosystem for the transportation (sub-industry of industrial services), energy and public service sectors. Paris is among the four major concentration hubs, alongside Frankfurt, London and Amsterdam. Over the last two decades, the development of data centers has accelerated in Île-de-France to reach a total of over 160 data centers, according to the database of L'Institut Paris Region.

For the territorial administrations, communes and intercommunal structures first of all, the siting of a data center is often perceived as an asset. A sign of digitalization and economic development, data centers were able, for example, to help reinvest an aging logistics hub or abandoned buildings in certain communes. But the sitings of data centers also have negative repercussions to a varying degree on the territories. According to their size, how their type is integrated into the site, their installation process and their host territory, the energy and environmental impacts can be more or less significant,[6] with on one hand, increasingly larger buildings (as much as several dozen thousand square meters) and very high electricity consumption (as much as several dozen megawatt hours) and, on the other, shared objectives of "zero net land artificialization [ZAN]" and "zero net emissions [ZEN]." At a time when the data center projects in Île-de-France have reached unseen levels of space consumption and electrical power (4 GW for the operator RTE alone, or the equivalent of adding a consumption of 4 million new inhabitants to Île-de-France region), it seems indispensable to

1. Diguet Cécile and Fanny Lopez (co-dir.), "The spatial and energy impacts of data centers on the territories," ADEME Report, 2019.
2. Lopez Fanny and Gawlik Maximilian (codir.), « Data centers: anticipating and planning digital storage", Note rapide, n° 45, L'Institut Paris Region, May 2021.
3. Term corresponding to the Paris region market.
4. In 2021, the Global Security Mag counted 215 neutral data centers in France, of which 73 in Île-de-France. In the 2022 update, only 161 were counted for France, of which 45 for Île-de-France. This difference is principally explained by the merging of the "points" of the sites counting several data centers (for example, only one "point" is counted for Data4 in Marcoussis, compared to 15 previously). https://www.globalsecuritymag.fr/-CARTOGRAPHIE-DES-DC-NEUTRES,13-.html
5. GXI Indice d'interconnexion mondial Vol. 5, Mesurer la croissance de l'économie numérique mondiale, Equinix, Inc. (2021)
6. Cécile Diguet and Fanny Lopez (codir.), *ibid.*

better regulate, in the future and as of today, the development of data centers in Île-de-France. The "tertiary" decree[7] will also have consequences to anticipate in the matter.
The data centers and data flows that permanently cross the region are not exactly proportional to the data consumption in Île-de-France itself. Whereas the location in proximity to the broadband transmission networks or very high-voltage electricity substations is strategic for the operators and investors, the data do not often have a direct relationship with the needs of companies, administrations or inhabitants of its territory or even the region where it is sited: the estimate by the public actors of the "right" level of data center development within a given territory – between a territory's own needs today or tomorrow and the solidarity with farther neighboring territories – is consequently particularly difficult.

Objectives

This study proposes to shed light on the direct and indirect effects of the siting of data centers in Île-de-France, as much in terms of risks as of opportunities. It intends to give territorial administrations the keys to understand, act and invite all the actors in regional and territorial development to create a better connection concerning this strategic issue.
This work consequently aims at sketching possible futures for a more organized development of data centers as well as proposing recommendations for a better integration. The fourth part thus proposes a list of criteria to better evaluate the projects: to go beyond PUE (Power Usage Effectiveness) alone and develop a genuinely systemic vision.

Method

Since 2014, L'Institut Paris Region (IAU Île-de-France at the time) has been working on the subject of data centers, initially connected to flooding issues and on questions regarding the recovery of heat produced. The report *The Spatial and Energy Impact of Data Centers on the Territories* for the ADEME in 2019 made it possible to deepen our research, as well as several digest notes, story-maps and non-public studies that had been conducted on data centers. This research was followed by numerous external exchanges with L'Institut's partners (DRIEAT, ADEME, RTE, Enedis and Choose Paris Region as well as with certain actors in the public sector such as consulting firms and data center operators). Since 2020, a working group has brought together, internally, several of L'Institut's departments (Urbanism, Development and Territories, Energy-Climate, Economy and Environment). These departments were also involved in this publication.
Since 2014, L'Institut Paris Region has been enriching and regularly updating the data center database. It is an essential support for this document, serving both to propose a typology of data centers and illustrating the recommendations, on one hand, by resituating the existing data centers on the regional maps of issues, and on the other, by identifying good practices of existing data centers.
By relying on these experiences and prior research, this work makes it possible to take into account urban, energy, economic and environmental issues.

7. Stemming from the Élan law, the tertiary decree or "tertiary eco-energy plan," published in July 2019, imposes buildings in the tertiary sector to make significant energy savings. The operators are under the obligation to reduce consumptions to under 40% by 2030, 50% by 2040 and 60% by 2050. The objectives are gradual: they can be reached in relative or absolute value.

1 • DECODING COMPLEXITY TRENDS

1.1 DATA CENTERS, AN ESSENTIAL COMPONENT OF THE "DIGITAL SYSTEM"

Definition and composition

Data centers are digital data hosting buildings. With networks (that are optical fiber, copper networks and wireless networks) and user terminals (smartphones, computers, etc.), they comprise the digital infrastructure that makes it possible, by using dedicated applications, to provide "digital services."

Data centers have been developing since the 1990s due to several factors, notably:
- the explosion of the commercial web;
- the deregulation of the telecom market;
- the replacement of mainframe systems by server systems;
- the digitalization of companies and cultural contents.

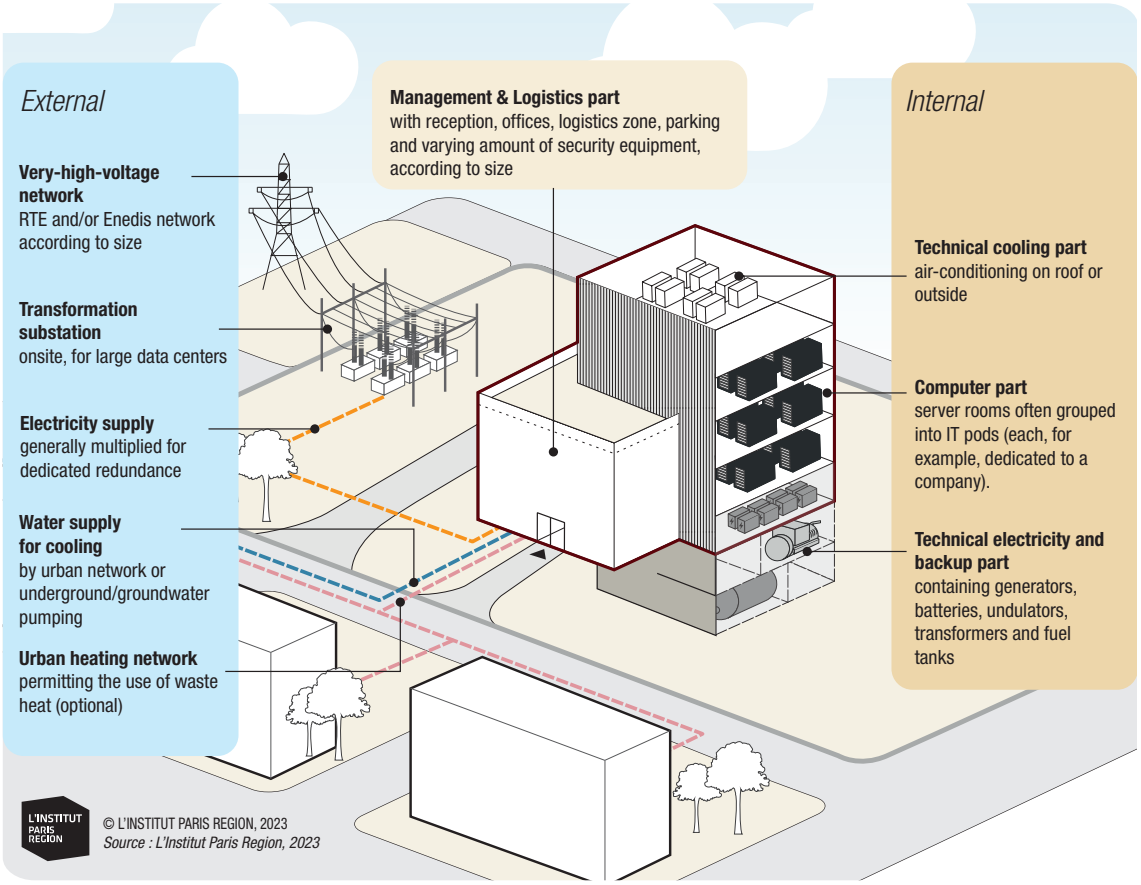
A data center is composed of two major components:
- **The computer part** with IT rooms. Data flows are handled here and the racks and cabinets containing the servers are housed here.
- **The infrastructures for technical functioning:** security, cooling and ventilation and electrical current distribution (undulators, transformers) systems.

The data center is a physical space that has three main functions:
- data processing;
- data storage;
- data transport management within digital networks.

A data center, through data processing or even simple storage in the servers emits heat (by the passage of an electrical current in a conductive material presenting resistance (Joule effect), called **waste heat** because it is most often neither recovered nor recycled. It must therefore be equipped with **cooling systems**[8] to maintain the equipment at a certain temperature. There is also backup equipment: batteries, UPS (Uninterruptible Power Supply), generators and heat recovery systems.

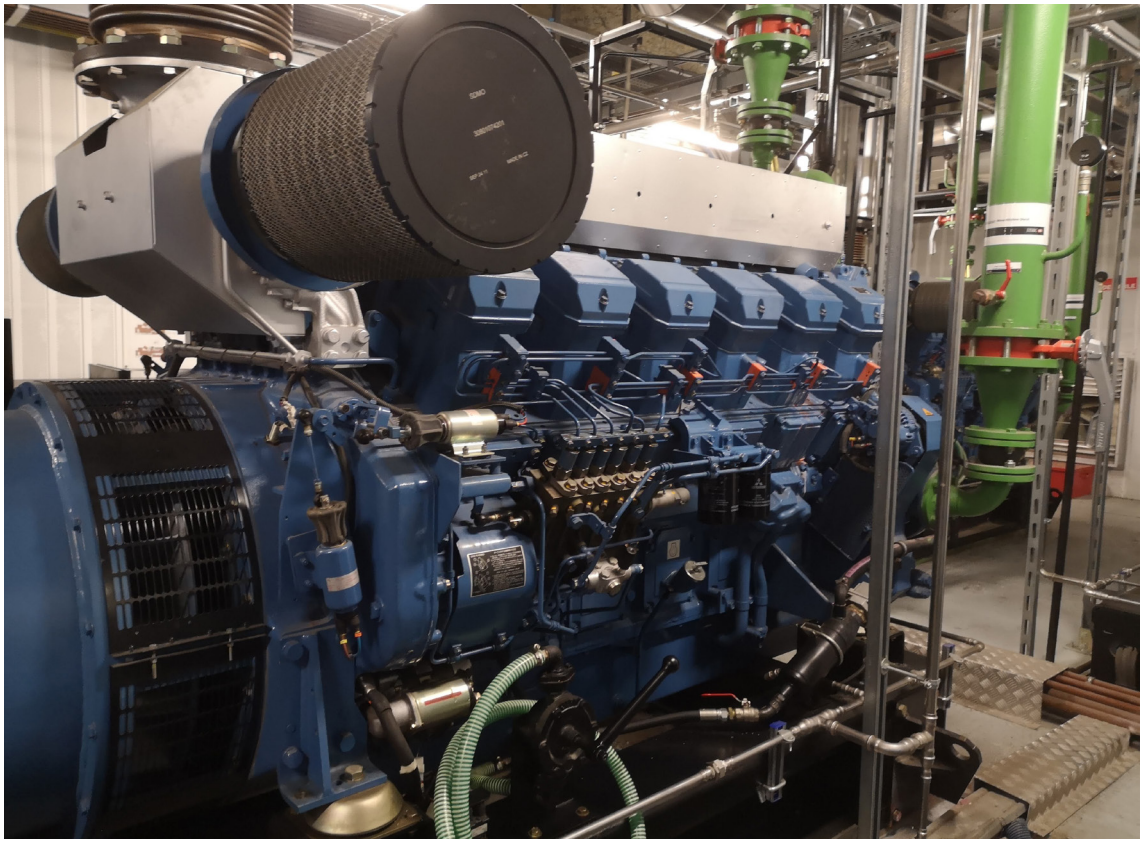
8. There are different cooling techniques such as the air treatment of a IT room by ice water, air cooling (free cooling), adiabatic cooling, liquid cooling. There is an enormous difference in energy efficiency between these different methods.

THE FUNCTIONAL COMPONENTS OF A DATA CENTER



The data center operates different technologies depending on application needs, for example, for computing servers, high-performance computing centers, storage racks or network equipment for telecom operator centers. Software differs from one type of data center to another. The data center building also has spaces dedicated to its functioning and logistics (reception, offices and logistics) that are more or less large.

Data centers are dependent on energy operators (electricity production, transport and distribution), as well as telecom operators.
Data centers are not only connected to user terminals but they also function in a network with other data centers. The interconnection between data centers means that they sometimes establish exclusive links between buildings.



Euclyde DC6-IDF data center in Lognes, in Seine-et-Marne: building, server racks, cooling equipment, backup generator.
Source : L'Institut Paris Region, 2022.

Data centers, a particular component of the "digital system"

Within the "digital system," data centers comprise a particular component, certain of whose characteristics should be underlined:

- **Strong "load sensitivity,"**[9] unlike, for example, optical fiber networks: **the more digital data that is produced, exchanged and stored**, the more **energy, water and space used by data centers,** even if it is not exactly proportional, due to certain efficiency gains; consequently, the impacts of data centers increase more quickly than those of the entire digital system and therefore the weight of data centers, relatively limited today in the impacts of the digital system, tends to increase;
- **Growing virtuality:** data centers comprise today one of **the most relocatable** components of the digital system, even if certain uses require latency times or security/sovereignty conditions that limit the possible distancing between the places where the data are used and the data centers; in other words, on the regional and even more so the territorial scale, the imbalance between the impacts (more negative) of data centers and the impacts (more positive) of digital services tends to increase, in the same way as **the gap between "serving" territories and "served" territories; moreover, this growing virtuality reinforces the image of data centers' "black boxes,"** and therefore fears regarding their environmental impacts and expectations concerning the evaluation of these impacts;
- **Growing visibility in the public space;** paradoxically, it is in fact in a booming period of the virtualization of digital data processing and storage, over the last few years, that data centers have, in Île-de-France, erupted in "the public space" in the literal sense (they have become more visible and more significant[10]) as in the figurative sense (they have become a object of debate and controversy).

Data centers, specific buildings and sites

According to the technical and functional definition of the "Definition and composition" part, all data centers have both shared characteristics and particularities that distinguish them.

Characteristics that all data centers share

1. Technical characteristics of the building
   - Extreme robustness of the structures and floors, to support the floor load (weight of the servers and technical installations): between 500 kg and 1 t/m²;
   - Adaptability for cable routing.
   - High ceilings (often over 4 meters);
   - Flexibility of interior spaces and large open floor plans, minimum number of posts.
2. Specificities of form, volume, density and program
   - For new construction, the image of the box persists. They are often single-story rectangular buildings in zones where there is little or no real estate development pressure, if not ground floor + 3 or 4 stories. Significant height is rare except in certain American or Asian cities.
   - In older construction, they can be housed in an existing building provided that they offer very large spaces or solid floors (former department stores or buildings used by the press, the textile industry, etc.), even infrastructures: military site, port building (former logistics sites), former factory, often already equipped with sites for backup generators, fuel oil tanks, water tanks, etc.
   - In existing as well as new construction, a bunker in the imaginary dimension (information bunkers) exists. The data center is an ultra-secure surveillance architecture, even if the campus typology makes it possible to push back part of the control systems to the exterior. We can however note a progression of the closed black box to an opening that has a greater relationship to the exterior (windows on the façade, improvement of surroundings) as well as the interior (transparent partitions).
   - The space is generally partitioned into three groups: the office and logistics area (with reception, office, logistics, maintenance zones), the IT area and the technical area. The IT area is almost equivalent in terms of floor space to the technical area: undulators, cooling systems, backup generators, batteries, etc.

9. This sensitivity is not belied by the mobilization of "zombie" servers, put forward in the IEA (International Energy Agency) report of 2022.
10. The significance of data centers in the public space in the literal sense is the main form of the digital system's "materialization" in Île-de-France, in France and in Europe. Moreover, this materialization can take other forms, whether it concerns, for example, giant mines for extracting rare earths or giant factories for manufacturing smartphones.

- It is a heavily partitioned space with little programmatic variation. We never see spaces that cross the heart of the data center where the data cabinets (sometimes partitioned by the customer with its own security systems) are; the circulations and technical spaces surround the central storage space, with office spaces and sometimes a cafeteria.
- A mixed program is rare.
- The technical equipment is more structuring than in the other programs. The separation of spaces and temperatures plays a key role in the infrastructure's efficiency. It concerns isolating climates and creating milieus: cool aisles, warm aisles, climate chambers, exhaust stacks, space for backup generators, various vats and tanks, cooling towers, undulators, battery rooms, control room. Some of this equipment is generally placed on the building's roof or alongside it.

3. Surroundings and siting plots that are secure, isolated and often well-cared for

- Data center sites are often fenced-in, equipped with surveillance cameras, opaque and very secure. The building's use is rarely signposted at the plot's exterior.
- Buildings reserved for data center use are often sited in the center of the plot and the possibility of accessing the façade from the public space is very rare.
- To leave space for future expansions, very large plots are often used in less restrictive situations.
- The parking areas are often oversized. Depending on the local urbanism plan in effect, the number of parking places required corresponds to the floor area and not to the operator's real needs.
- For large-scale urban expansion projects, they include a large planted part, which can be accompanied by a high-quality landscape treatment.

Some of these points contribute to the dissection or rupture effect in the continuities of human and ecological flows.

Data centers are extremely sensitive objects for the project owner (in terms of security, accessibility and continuity of the electricity service). Experimentations or daring energy projects (in-situ energy production units through mini-wind turbines or photovoltaic panels) remain very rare. In Île-de-France, there are very few atypical data centers such as underground installations or in mixed programs (the hybridization of these infrastructures with other types of uses) that go beyond the sole sharing of the building with offices.

There is therefore a great diversity of sizes, forms, functions, technical and operating modalities.

In Île-de-France, there is a great variety of host territories, forms, ages and types of data centers.
Source : L'Institut Paris Region, 2023.

If they have shared characteristics, data centers present a very great technical complexity, a spatial history, very strong links to the electricity system... There can therefore be multiple typologies depending on the issues to be addressed. Here are several families of criteria that the operators deal with, and others that we propose for the following analyses.

Criteria on functioning:

1. **The principal functions:** division of the three functions (computing, storage, transport / networking / management) within the data center.
2. **The degree of internet connectivity of the operators:** on an internet backbone (internet highway) or a local loop.
3. **The type of data center:** infrastructure or colocation data center (hosting outsourced by the customers) and corporate data centers (built by or for a company or public entity).
4. **The function/position in the data center ecosystem.** A very simplified typology is as follows:
   - **Data center « core ».** Located in the heart of a city, near the customers (finance...), these data centers are based on the principles of interconnection and very low latency. Generally small, they can also range from medium to large (in exceptional cases). Example: Telehouse Voltaire, Paris 11th arrondissement (7,000 m²);
   - **Data center "of proximity."** These data centers are for the most part colocation data centers. Example: Marilyn in Champs-sur-Marne (77);
   - **"Hyperscale" data center.** Generally very large (> 10,000 m²), these data centers have a very specific architecture, standardized for greater efficiency and so that they can be modulated. Unlike data centers of proximity, the hyperscale structures generally have their own technical equipment (racks, cabinets) without subcontracting and offer cloud service. The traditional operators of these data centers are actors like GAFAM or BATX.[11]

There are other more hybrid forms. Certain older data centers or those dedicated to specific public or private customers (banks, customs...) do not fit into these categories. Taking into account regular technological progress, these categories can evolve over time.

5. **The level of information ensurance :** through a classification by level called Tier and managed by the Uptime Institute[12]: Tier 1 being the least redundant (availability of 99,67% or 28 hours of accumulated annual shutdown), Tier 4 being the most reliable (reliability at 99.9%). Redundancy means that the data center's technical equipment is duplicated (equipment, links, power supply and cable routing, data, software, etc.) with the aim of guaranteeing its functioning in the event that one of these components would prove to be deficient.

Criteria concerning the actors involved (managers and customers):

6. **The nature of the managing operator:** operator (private organization, research center, bank, insurance company, institution...), infrastructure (colocation or cloud operator).
7. **The origin of the operator's activity sector:** telecom, telephony (Bouygues, SFR, Orange...), internet telecom (Celeste...), real estate, technology and digital giants (GAFAM, BATX)...
8. **Operator's action scope:** international (notably GAFAM, BATX), national, regional.
9. **The nature of the customer(s):** private actors (companies and private organizations, banks, insurance companies...), public and parapublic actors (customs, Banque de France, local administrations, universities and research centers...).

Criteria on buildings:

10. **The IT area**[13]**:** the work of L'Institut Paris Region is generally based on the following ranges of IT area:
    - Small data center: between 1 and 500 m² of IT area;
    - Medium data center: between 500 and 2,000 m² of IT area;
    - Large data center: between 2,000 and 5,000 m² of IT area;
    - Very large data center: between 5,000 and 10,000 m² of IT area;
    - Giant data center: over 10 ,000 m² of IT area.

11. **The size of the hosting building:** generally speaking, in France, the ratio between the IT area ("white space") and the area reserved for technical, production, logistics and management spaces ("black space") is about 50/50. This means that the building's floor area often represent twice the IT area. A large number of data centers contain offices that can increase the floor area.

11. Hyperscale initially designated a data center that can rapidly adapt to heavy demands for resources.
12. Consortium of companies created in 1993 and whose objective is to maximize the efficiency of data centers.
13. Also see Part 2 of this report on the size of a data center and the relationship between the absolute area and the IT area.

Energy criteria:

12. **Connection power:** ranging from a few hundred kW to several dozen, even hundreds of MW.

To go further in our reflection, L'Institut proposes also considering the following criteria:

Temporal criteria:

13. **The period went the data center went online:** from the end of the 1990s to today, the data center sector has been in constant evolution thanks to technological progress. The latest generation of data centers is notably distinguished by a better energy performance.
14. **The period when the hosting building was built.**

Spatial criteria:

15. **The global location:** in communes in the heart of the metropolis, the dense conurbation, the mostly urbanized space, metropolitan outskirts...
16. **The local urban environment:** more or less dense urban fabrics.
17. **Land units ("sites"[14]):** large or contained (island of contiguous ownership, composed of one plot or a group of plots).
18. **The location or not in a data center cluster.**
19. **Programming of the building:** building with mixed programming or reserved for a data center use.
20. **Initial purpose of the building:** specialized building (hosting of the data center considered from the building's creation) or transformed building (building converted later to host the data center).
21. **The installation process:** linked to the preceding subject. In an existing building, the data center can be inserted in it or the building transformed to make it usable for its needs. In a new construction, it can transform an already artificialized plot or densify such a plot or build over open ground, farmland or forest.
22. **The integration of the data center into its site:** in a building occupying an entire land unit, in a building on a larger land unit, in a building on a private campus (company park or campus of a private group). This has repercussions on the visibility of the data center, on the externalization of the technical and logistics elements...
23. **The Land Use Ratio that,** connected to the previous point, calculates the land take of the building that hosts the data center on the entire land unit.

These multiple criteria suggest many ways to classify data centers. Part 2 of this study will propose, using the database of data centers in the Paris region, **a typology favoring spatial criteria.**

Among the data centers in the Paris region, former telecom buildings as in Vélizy-Villacoublay (above), new constructions as in Marcoussis (p. 17 top) and transformed office buildings as in Lognes (p. 17 bottom, now closed).
Source : L'Institut Paris Region, 2021.

14. As concerns what follows, our definition of the site therefore corresponds to that of a land unit.

Two data centers installed in the Plaine Saint Denis: Equinix's PA6 in Aubervilliers, built in 2008, (left) and Digital Realty's (Interxion) PAR5 in Saint-Denis, built in 2009 (right). Source : L'Institut Paris Region, 2023

1.2 ÎLE-DE-FRANCE, A PRIVILEGED HAVEN FOR DATA CENTERS?

A growing and mutating worldwide data center market

Since the early 2000s, we have observed strong and continuous growth of the data center market, which is principally explained:

- **by the digital transformation of companies and administrations**[15] as well as the gradual outsourcing of the processing and storage of their data, earlier divided among scattered local facilities;
- more broadly, by the **digital transformation of all human activities** (health, education, culture, leisure, etc.), which has brought about strong growth in the volume of data exchanged (+26%/year on the networks in the world between 2015 and 2020 according to Cisco cited by The Shift Project,[16] +35%/year in data centers) and stored (+40%/year in data centers), under the combined effect:
  - **of the multiplication of connected equipment, smartphones** (+9%/year for smartphones) but also connected objects (the Internet of Things or IoT, with an estimate of 3.6 pieces of equipment per person in the world in 2023, or the Industrial Internet of Things or IIoT, with an estimate of 7.5 billion connected industrial interfaces in 2020 according to The Shift Project[17]);
  - **of the multiplication of applications** (as many as 258 billion downloads projected in the world in 2022 according to the professional association France Datacenter[18]) and uses (streaming, cloud gaming, social networks, etc.) paired with a growth in the graphic definition of images and videos (HD and Ultra-HD), notably bringing about the growth in mobile data volume exchanged six times faster (+60%/year between 2015 and 2020 according to The Shift Project[19]) than that of smartphones;
  - **of the gradual creation of groups of big data** requiring new storage capacities and especially new processing capacities, notably in the framework of artificial intelligence, to which should be added the specific needs connected to the rapid development of cryptocurrencies.

This quantitative growth of the data center market, which should continue at a strong rhythm at least until 2030 while perhaps undergoing pauses similar to the one caused in 2000 by the bursting of the internet bubble, has been accompanied by a major qualitative mutation.

In fact, although extremely promising, the data center market is still not mature and competition remains very strong between the different models. The majority model is still currently that of a neutral medium-size data center generally proposing a hybrid offering (combining colocation and cloud IT service, generally called cloud, both public and private[20]) to meet the diversity of requests from a growing number of companies and administrations that wish to outsource the hosting of their data, applications or information systems. However, **the model that is currently undergoing the strongest growth in the world**, in percentage as well as in volume but with differences according to the region, **is that of the large-size data center exclusively proposing a cloud offering**, mainly public (in the meaning of "open to all publics").

To distinguish this model from the proceeding one (colocation data centers or neutral data centers or traditional data centers), we can speak, alternatively and always is a slightly simplified manner:

- of cloud data centers to evoke the massive virtualization that accompanies this movement;
- of giant data centers to emphasis their size;
- of hyperscale data centers to stress the modularity and adaptability of these centers to the increase in the volume of data to process or store for their customers,
- of self-built data centers, to evoke the transition of internet giants, once mainly tenants of IT rooms inside colocation data centers and now principally digital service providers inside data centers that they build and manage themselves.

15. On the question of digital transformation, notably see Boston Consulting Group (BCG) "L'impact de la crise sanitaire sur la maturité digitale de la France - 2ème édition de l'étude BCG x MEDEF sur la maturité digitale de la France," June 2022.
16. On the growth dynamics of the digital, notably see the computer graphics proposed by The Shift Project "Impact environnemental du numérique : tendances à 5 ans et gouvernance de la 5G – Note d'analyse," March 2021, p. 25.
17. The Shift Project, *ibid.*
18. See France Datacenter, "Qu'est-ce qu'un datacenter ?," 2022. France Datacenter "brings together all the actors of the data center ecosystem in France. It represents and ensures the promotion of the sector as a base of the performance and reliability of the digital economy."
19. The Shift Project, *ibid.*
20. A private cloud service is a service entirely controlled by a single organization and is not shared with third parties. On the contrary, a public cloud service is a subscribed service that is also proposed to all the customers that want similar services.

Still a minority on the worldwide scale, this cloud data center model is capturing an increasingly greater share of the growth in volume of the data exchanged and stored by data centers. The estimates and projections on the worldwide scale are still very variable from one observer to the other, but a report by the Austrian Environmental Agency of the European Commission[21] was able, by synthesizing many research projects, to conclude that, for the 27 members of the European Union, **the share of cloud data centers in the energy consumption of all data centers was 10% in 2010, 35% in 2018 and should reach 60% in 2025.** Consequently, between 2018 and 2025, while the total energy consumption of European data centers was to increase by +21%, that of cloud data centers should almost double (+107%, compared to -26% for the other data centers).

As cloud data centers have on average better energy efficiency than that of other data centers, the growth in volume of the data exchanged and stored by these data centers should clearly more than double between 2018 and 205, to such a degree that The Shift Project adapted, in 2020, its method of estimating and projecting the global energy consumption of data centers to better take into account the specificity of cloud data centers.

The very strong growth in the cloud data center market has been accompanied by a very strong concentration in the hands of a limited number of international operators, internet giants, often described as hyperscalers. According to a report by the Synergy Research Group,[22] **Amazon (under the name of Amazon Web Services or AWS), Microsoft (under the name of Azure) and Google had, in 2022, nearly half of the 730 largest cloud data centers or hyperscale data centers in the world**, generating nearly two thirds of this market's revenue (33% for AWS, 22% for Microsoft Azure and 10% for Google) and have experienced a growth in their revenue on the order of +35 to +50%/ year, compared to +10% to +20+/year for the other cloud operators (other than Chinese).

A third component is currently emerging in the international data center landscape, that of edge data centers.[23] This concerns groups including one to several servers occupying a reduced space in a locale or even a simple cabinet, intended to temporarily store and instantaneously process the data as close as possible to the sensors deployed notably to steer an urban service (for example, the circulation of autonomous vehicles) in order to avoid the latency time and the energy consumption linked to the transfer of data to a larger data center.

These micro-data centers organized in a network around traditional data centers or, increasingly often, cloud data centers, should represent 12% of the total energy consumption of all the data centers in the 27 countries of the European Union.[24]

Thus, the international data center landscape is very heterogeneous today, through the type and size of data centers as well as by the nature and action scope of its operators.

In the next few years, **this landscape could very much simplify, at the expense of traditional medium-size data centers, oriented toward colocation and managed by regional or national operators, and to the benefit of a model combining cloud data centers and edge data centers.**

However, this model could at the same time become more complex, notably with the emergence of an intermediary component, the cloud at the edge, that certain researchers[25] consider indispensable today to technical performance and especially to the model's energy efficiency.

21. European Commission, « Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market », 2020.
22. Synergy Research Group, "Hyperscale Cloud Market Tracker– 2022 report," 2022. Paying report not consulted by L'Institut Paris Region but the object of several articles online notably https://www.lebigdata.fr/1200- data-centers-2026 and https://www.silicon.fr/infrastructure- cloud-aws-azure-google-437850.html. The report more particularly takes an interest in 19 "worldwide giants" of cloud computing (software on demand, online businesses, social networks and online games), among which Alibaba, Amazon, Apple, Baidu, ebay, Facebook, Google, IBM, Microsoft, Oracle, Tencent, Twitter and ByteDance.
23. Attention, one could think as the edge cities, peripheral urban spaces concentrating jobs and services – the edge data centers – are located in the outskirts of cities and metropolises. In fact, the inverse is probably true: the edge data centers are functionally located on the periphery of digital systems, but geographically concentrated in the center of cities and metropolises.
24. European Commission, *ibid.*

Digital Realty (Interxion) data center, rue du Rateau in La Courneuve (93). Source : L'Institut Paris Region, 2021.

This perspective is interesting because, with a "galaxy of clouds"[26] hosted by data centers of very diverse sizes and not only by giant data centers, the buildings or at least the sites of traditional centers that had become obsolete would be likely to take, tomorrow, all their place in the spatial reorganization of the offering, notably due to electricity availability, the presence of a local digital ecosystem…

25. On this subject, notably see the work underway at the CEA in the team of Florent Kirchner, head of the department of software and systems engineering and co-initiator of the Programme et Equipements Prioritaires de Recherche "Développement de technologies avancées de cloud" (https://www.cea.fr/presse/Pages/actualites-communiques/ ntic/quel-avenir-pour-le-cloud-face-aux-enjeux-de-frugalite.aspx)
26. The expression was coined by Florent Kirchner, *ibid.*

ILE-DE-FRANCE, AN ATTRACTIVE REGION IN AN ATTRACTIVE COUNTRY?

Europe, a continent that counts in the world of data centers

Europe seems to have more data centers than the United States (2,904 against 2,701, out of the 8,167 counted in the world in 2022[27]).

Moreover, the energy consumption of data centers in European Union countries, which had already increased by 42% between 2010 and 2018, should first grow by 21% between 2018 and 2025, to reach 92.6 TWh per year, with an increase in the concentration of energy consumption in the northern and western countries of the EU, whose share should increase from 82% in 2018 to 87% in 2025.[28]

Île-de-France, a hub that counts in the Europe of data centers

An intermediate position

Four countries concentrate over half of European data centers (1,488 out of 2,904[30]) and, in each of them, an economic regions concentrates at least a third of the country's data centers (in number and undoubtedly, but information is not available, a still greater share in area and especially in installed electrical power: London (193 data centers out of 456 in the United Kingdom), Frankfurt (123 out of 487), Amsterdam (119 out of 281) and Paris (113 out of 264[31]), together often called "FLAP" by the data center market analysts, who often add Dublin to it (46 data centers out of 49 in Ireland) to form the group "FLAP+D;"

27. Data centers counted on September 15, 2022 on the platform Cloudscene (https://discover.cloudscene.com/search/data-centers)
28. European Commission, "Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market," 2020.
29. The main ones can be cited: Data center pricing (www.datacentrepricing.com), Cloudscene (https:// cloudscene.com/), DC-Byte (https://dcbyte.com/)...
30. Data centers counted on September 15, 2022 on the platform Cloudscene (https://discover.cloudscene.com/search/data-
31. Paris thus represents 42% of the country's data centers according to Cloudscene's counting. Other counts give significantly different proportions, but also using different definitions. For example, in its recent publication "Guide pratique à destination des élus franciliens" (2022), Choose Paris Region refers to the "2021 Mapping of the 215 neutral data centers (that is, colocation data centers) in France" to count 74 data centers in Île-de-France, or 34% of the country's data centers. In addition to the number of data centers, the platform Cloudscene also proposes the number of providers (hosted in colocation data centers) to classify the regional markets among them. In number of data centers it is Lille that arrives in second place after Paris, with 18 data centers (for 62 providers), whereas in number of providers it is Marseille, with 357 providers for 10 data centers.

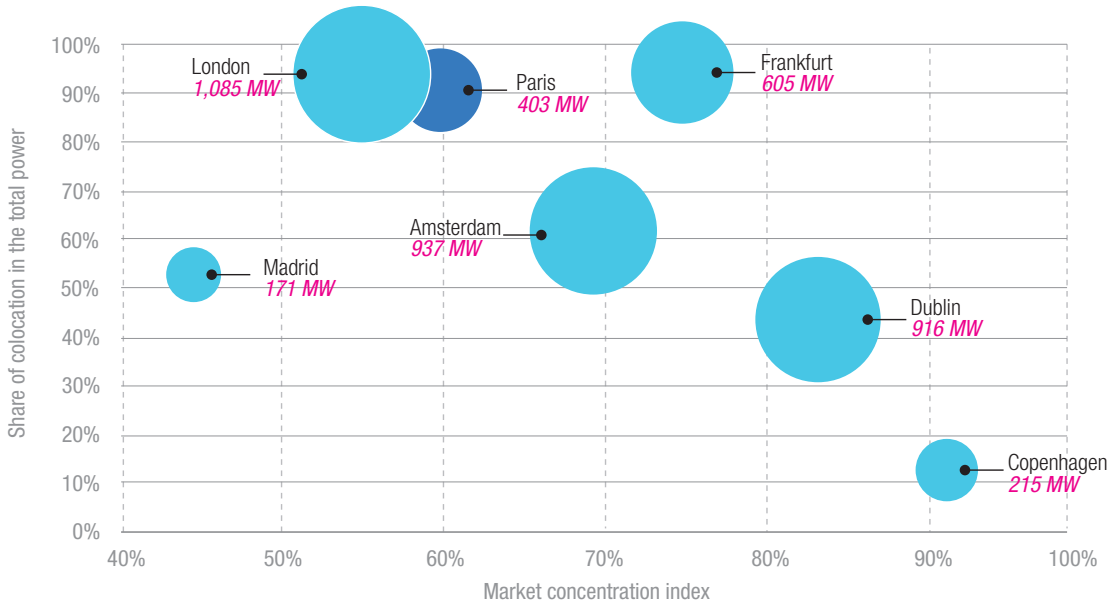
"Figures and sources"

To evaluate the relative weight of data centers in the world, Europe, France, Île-de- France and in other large European metropolises, we have a host of sources of information the most often difficult to cross-check because of:

- differences in technical perimeters, that is, the differences between the definitions considered for a data center (for example, the Synergy research group concentrates on hyperscale data centers where the Data Center Map favors colocation data centers);
- the difference in geographic perimeters (for example, Cloudscene considers that Marcoussis, Élancourt, Les Clayes-sous-Bois and even Asnières-sur-Seine are not in the "Paris region");
- the difference in variables used: number of data centers, number of data center buildings, number of data center sites (land units), area of data center buildings, area of data center sites (land units); "reserved" electrical power, effectively "connected" (with or without double counts in the case of redundancy), effectively "installed" (corresponding to the sum of the power of IT and infrastructure equipment effectively connected at a given moment); revenue; "footprint" that can however cover multiple realities; on the other hand, it should be noted that the number of direct or indirect jobs linked to data centers almost never appears in the available information;
- and of course the difference in dates, which is often the case in other sectors but that constitutes a particular difficulty in a sector like that of data centers that evolves very quickly.

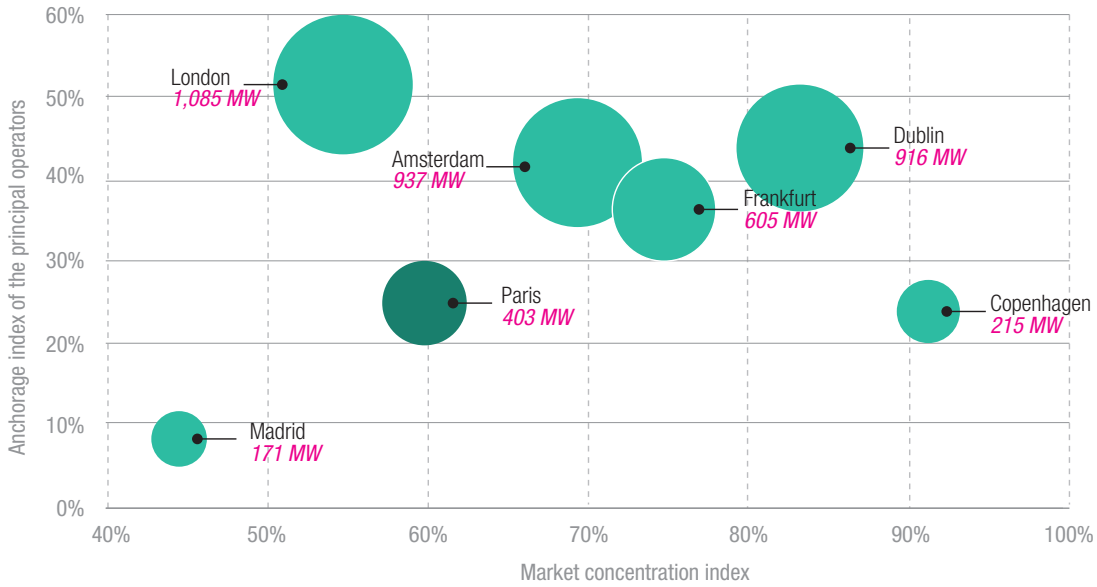
Furthermore, it should be noted that almost all the information available – some of it partially free – on data centers is produced by private actors,[29] notably with the aim of better knowing the markets and thus orienting their customers to solutions for outsourcing the management of their data. It is a little as if real estate agencies produced almost all the sources available on housing.

PRINCIPAL CHARACTERISTICS OF THE 7 EUROPEAN HUBS



The area of the colored disks is proportional to the total installed power (in service or under construction) of the hub in the 2nd quarter of 2021, indicated under the name of the hub.
Market concentration index: ratio of the installed accumulated power of the 5 principal operators of the hub and the total installed power of the hub.
Share of colocation in total installed power: attention, for lack of a sufficient detail in the available data, this share is calculated on the power of existing data centers (in service or under construction) and for which the project was considered committed in the 2nd quarter of 2021, rather than on only the installed power of the existing data centers.
Source : DC-Byte / The Franck Knight Team, 2021-Q2 / Definitions and calculation of indicators: L'Institut Paris Region, 2022

CROSSED DEPENDENCE BETWEEN HUBS AND OPERATORS



As in the preceding graph, the area of the colored disks is proportional to the total existing power (in service or under construction) of the hub in the 2nd quarter of 2021, indicated under the name of the hub.
Market concentration index: ratio of the installed accumulated power of the 5 principal operators of the hub and the total installed power of the hub.
Anchorage index of the principal operators: ratio of the accumulated existed power of the 5 principal operators and the total existing power of these 5 operators in the 7 hubs considered.
Source : DC-Byte / The Franck Knight Team, 2021-Q2 / Definitions and calculation of indicators: L'Institut Paris Region, 2022

The heavy concentration of data centers in these four economic regions is the reflection of their long-standing importance in the economy of their country and the continent, the stronger digitalization of their economies and the intensity of the information exchanges between them.

Paris, London and Frankfurt are distinguished by a higher proportion of colocation data centers in the total installed power. Paris and London are also distinguished by a lower concentration of their market since the five operators that are the most present (Equinix, DATA4, Global Switch, Interxion and Scaleway) represent less than two thirds of the total installed power (see graph p. 23 top). On the other hand, Paris is also distinguished by a relatively limited anchoring of the five most present operators, for which the region only represents on average a quarter of the installed power in the seven European regions considered. In other words, Paris certainly has not until now "put all its eggs in one basket," but the operators concerned haven't either. The situation is somewhat different in London that, for the five most present operators (Equinix, Virtus, Ark, Digital Realty and Global Switch), represents on average over half of the installed power in all the seven European regions considered (see graph p. 23 bottom). Globally, the data available to compare the principal European data center hubs suggest that, if London, Frankfurt and Amsterdam have already asserted themselves as international service points, Île-de-France still plays a mainly national and regional role, essentially serving its own economy.

Multiple reasons for the strengthening of the position of Île-de-France

Many reasons speak could speak in favor of the reinforcement of the position of Île-de-France on the European data center market.

In a 2021 report,[32] the international leader of colocation data centers, Equinix, identifies Paris, in the European market, as the "fastest growing core metro and an important ecosystem location for Transportation and Energy & Utility."

In another report by the Arcadis consulting firm,[33] the Arcadis Data Center Index 2021 recognizes more largely France as a leading worldwide location for the siting of data centers. On the basis of an indicator aggregating "supply" and "demand" criteria, it ranks France in 9th place among the 50 countries studied, just behind the Nordic countries (Sweden 4th, Norway 5th, Denmark 6th and Finland 8th) but also far ahead of the countries that are currently leaders in Europe (United Kingdom 13th, Netherlands 19th and Germany 26th). Consequently, with a rapid and sure return on investment and a durable performance, the French market seems to be one of the most attractive for investors and operators.

According to this report, the main advantages of France are:

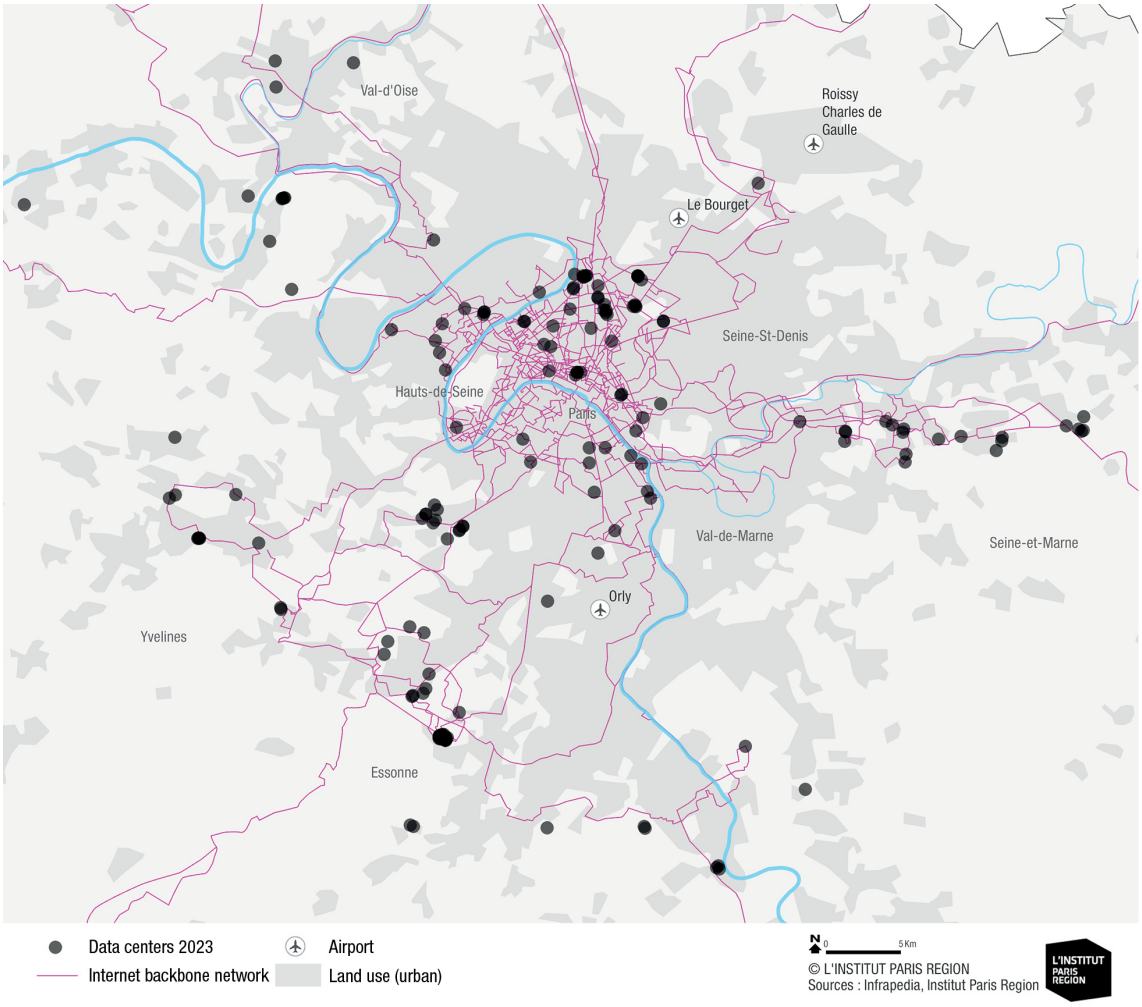
- **the size of its information and communication technologies market (3rd in Europe);** the report emphasizes that the French government has been accompanying the digitalization of its economy, investing 20 billion euros in broadband to reach each French household by 2030;
- **the size of its domestic market (**10th in the world);
- **the reliability of its electricity network;** the report also takes into account the price of electricity – for which France is situated in the average of the 50 countries studied — but not the largely decarbonated nature of French electricity, which constitutes a major advantage, notably put forward by the professional syndicate France Datacenter;
- **its level of cybersecurity.**

The Arcadis report however mentions a few of France's drawbacks (mediocre coverage in mobile broadband and relative difficulty in obtaining building permits), but does not bring up the relatively advantageous taxation (reduction of the rate of the domestic tax on the consumption of energy products for data centers).

It does not mention either France's good connection with other European countries, and also America and Africa through broadband transmission networks (internet backbone). Several underwater cables link Europe to North America from the French coasts of the English Channel and the Atlantic. Since Brexit, this favorable position of France has grown in importance, making it possible to create a direct link between the United States and Europe. This also makes it possible to ensure data flow to the rest of Europe and the Orient and more recently to Africa, by way of Marseille and the Mediterranean coast.

32. Equinix Inc., "GXI Global Interconnection Index Vol.5, Measuring the Growth of the Global Digigal Economy," 2021.
33. Arcadis, "The Arcadis Data Center Location Index 2021," 2021, https://datacenters.arcadis.com/locationindex/p/1

INTERNET BACKBONE NETWORK



The Arcadis report stresses the importance of Île-de-France, which concentrates 70% of the "footprint" of the country's data centers.[34] It could add:

- that many actors in the digital, data processing and data hosting sectors are located in Île-de-France where numerous companies and potential customers are found;
- that there is a dense fabric of service providers, indispensable for the management and maintenance of these highly specialized installations;
- that Île-de-France has multiple academic and research institutions that can also favor the siting choice;
- that it is also via Paris and Île-de-France that the broadband transmissions networks pass, in the great majority, between west and east and between north and south; even if a small part of the data that transit through the region are effectively used in it, this location contributes to the attractivity of Île-de-France.

In addition to these multiple attractivity factors for new actors, there are relocation factors for actors already present in France and Île-de-France. These factors are all linked to sovereignty and competitiveness:

- the European Union, through its general regulation on data protection, which protects the data themselves but also their extra-territorialization;
- the French government has taken measures on an industrial or label strategy ("trusted cloud" to prevent hosted data from being governed by laws other than French laws) as well as the digital transformation of administrations;

34. Data center footprint probably referring to the share of the domestic data center market.

- finally, the proactive and citizen behaviors of certain companies, which favor national hosting service providers, can also participate in strengthening the position of Île-de-France on data centers.

No sign of effective strengthening of Paris' position in Europe over the short or medium term

Despite these multiple reasons, the strengthening of the position of Île-de-France in Europe does not seem to show, at least in light of the comparative data available, any sign of materialization in the short or medium term.

In fact, among the seven European regions considered here (see graph below), Paris is ranked:

- sixth out of seven for expected growth in the medium term, expressed in MW, of installed power, ahead of Madrid, but with growth even close to twice as high as that of the Spanish capital (+178 MW against +113 MW);
- sixth for expected growth in the medium term, expressed in percentage of installed power, ahead of Amsterdam, but with a growth percentage twice as high as that of the Dutch metropolis (+44%).

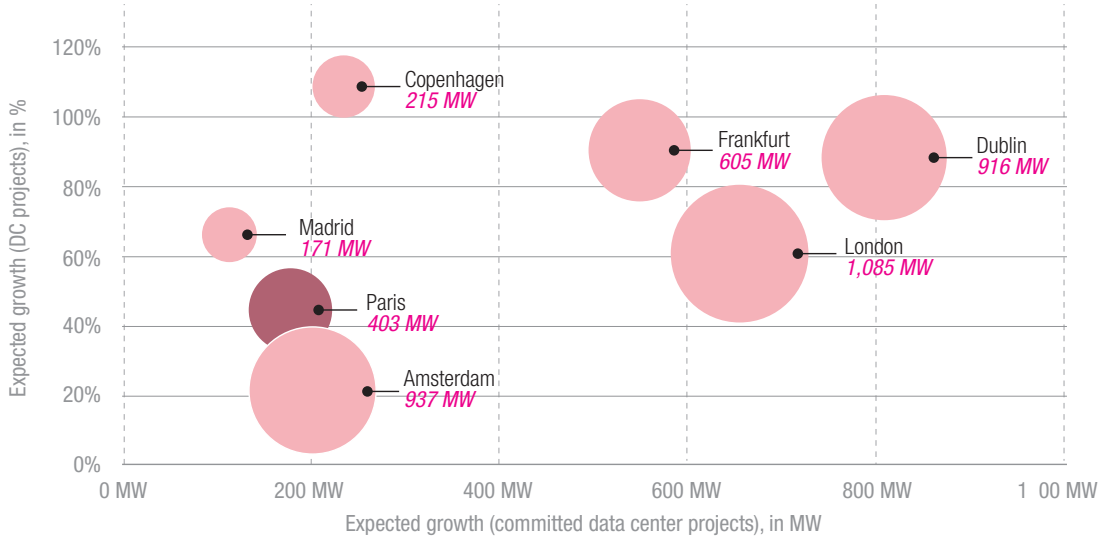
Nevertheless, very strong growth perspectives

The growth rate (+44%) of the projects undertaken in the short and medium terms in Île-de-France is however impressive.

It is to be connected to:

- the power recently contracted for by the data center operators with the sole transport operator RTE (end of 2023, it reached 4 GW or the equivalent of adding a consumption of 4 million new inhabitants to Île-de-France, without counting the power contracted for with the distribution operator Enedis, which is still not known).[35]
- the arrival of the American cloud actors (Amazon, Microsoft, Google and Oracle) in Île-de-France over the last few years.[36]

EXPECTED GROWTH IN THE MEDIUM TERM IN THE 7 PRINCIPAL EUROPEAN HUBS



As in the preceding graphs, the area of the colored disks is proportional to the total power of the existing data centers (in service or under construction) of the hub in the 2nd quarter of 2021, indicated under the name of the hub. Expected growth: accumulated power of the data centers whose project was considered committed in the 2nd quarter of 2021.

Source: DC-Byte / The Franck Knight Team, 2021-Q2 / Indicator definitions and calculations: L'Institut Paris Region, 2022

35. Today, almost all the data centers in the Paris region are connected to the Enedis electricity distribution network.

36. https://www.journaldunet.fr/web-tech/guide-de-l-entreprise-digitale/1514137-la-carte-secrete-des-data-centers-des-clouds-providers-americains-en-france/

The Digital Realty (Interxion) PAR 8-11 data center under construction in La Courneuve. Source : L'Institut Paris Region, 2021.

2 • ÎLE-DE-FRANCE : GROWTH AND DIVERSITY

2.1 DATA CENTERS IN ÎLE- DE-FRANCE: A RAPIDLY EVOLVING TYPOLOGICAL AND GEOGRAPHIC STRUCTURE

The analysis of the Paris region data centers makes it possible to observe a concentration in certain territories. It also reveals siting logics according to criteria such as the proximity of customers, land opportunities, electricity available and interconnection issues.

The territories[37] :

- **In the heart of the Paris conurbation,** data center siting and development are first linked to internet exchange points and the proximity of customers and companies. In Paris and the enlarged La Défense/Nanterre sector, data centers are often incorporated into a dense and mixed urban fabric. In this heavily networked area, they are inserted into transformed existing buildings (19th-century industrial, telephone or mixed buildings), basements, bunkers, etc.
- **Outside the heart of the metropolis, but still in a dense conurbation,** the siting of data centers is further explained by available and attractive land while remaining close to Paris. The plots are larger and the urban fabric was favorable to host them (former industrial fabric with numerous vacancies), the scales adapted and the prices affordable. Over time, these "serving territories" that serve large metropolitan spaces have now shifted to the digital. The concentrations have been confirmed, for example, in Seine-Saint-Denis (Saint-Denis, Aubervilliers, Pantin and La Courneuve). Thanks to the digital ecosystems that formed and the interconnection issues between data centers, a location close to these clusters seems even more strategic for certain actors than that in the heart of the conurbation.

Here, the data centers often occupy plots subject to urban recycling (change in use on a built plot) in former industrial or activity zones), and reinvestment of existing buildings such as former hangars. With land being increasingly rare in these territories, a new construction can reach several stories today.
For these two types of territories, the data centers are often integrated into mixed buildings that house several functions or activities (companies, offices, etc.).

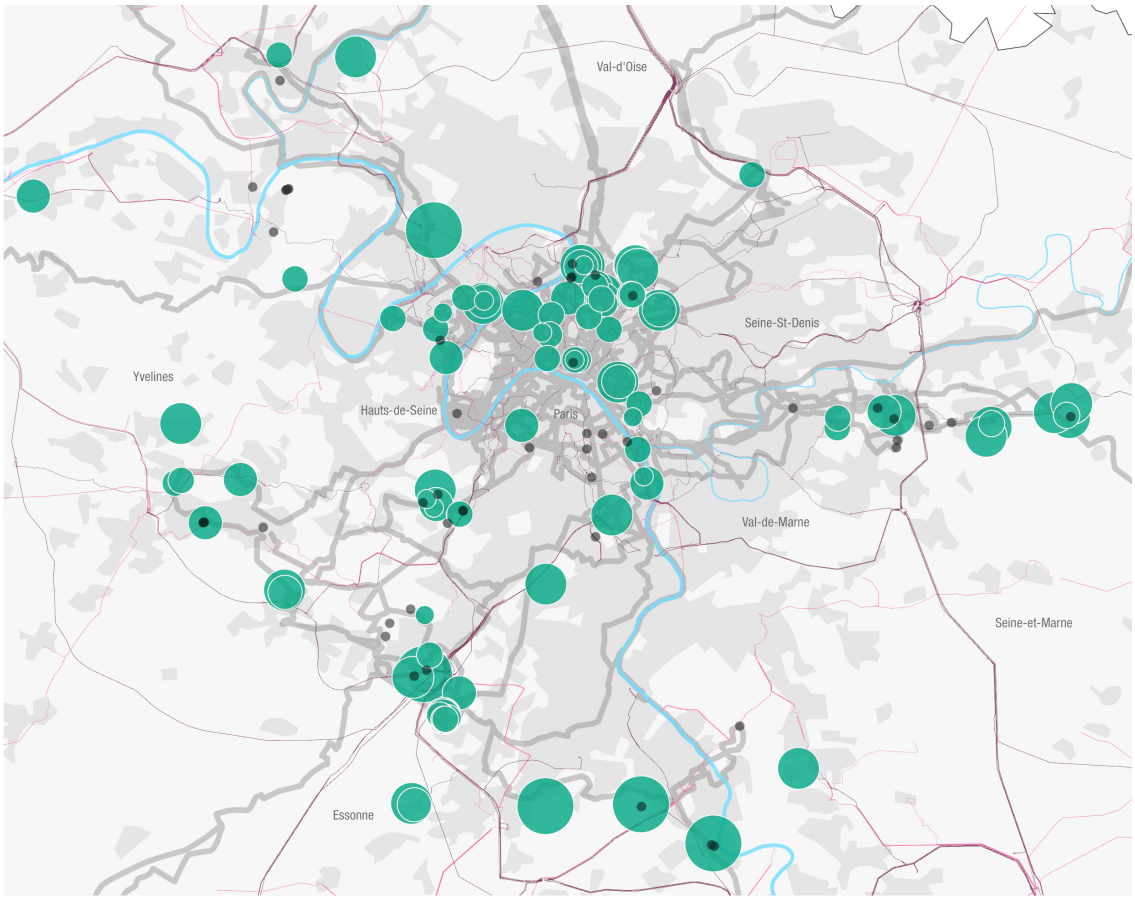
37. Inspired by the three types of territories: "hyper-urban gateways," "metropolitan outskirts" and "rural world and peri-urban territories" described in Diguet Cécile, Fanny Lopez (co-dir.), "Les impacts énergétiques et spatiaux des data centers sur les territoires" Note rapide, no. 828, L'Institut Paris Region, December 2019.

- **The peri-urban territories** are occupied by very large data center sites. Dozens, even hundreds of thousands of m² of servers per building were built around the Plateau de Saclay and along the A4 highway in Marne-La-Vallée. The installations often concern very large plots, in or alongside economic activity sites. These zones were previously farmland, even natural areas, but also former industrial sites. Such construction is rarely done following a land sobriety logic and a tall construction is rare.

Simplifying this observation, we can mention that different types of data centers (see "Data centers, buildings and specific sites") tend to be sited in certain of these territories.

Consequently, the heart of the conurbation is notably equipped with data centers dedicated to finance, edge computing, specialized and ultra-rapid data processing... while the medium and large actors in colocation, cloud and those linked to research tend to prioritize territories close to the heart of the conurbation and for so many less dense fabrics that are undergoing urban transformation. Data centers dedicated to one company, a large customer (insurance, banks, innovation, public data) or the hyperscale actors are more easily sited in contexts that are not dense and are not undergoing urbanization.
On the following pages, L'Institut Paris Region proposes a more detailed analysis of the database of data centers that allows for a better comprehension of the typological-geographic structure of Paris region data centers.

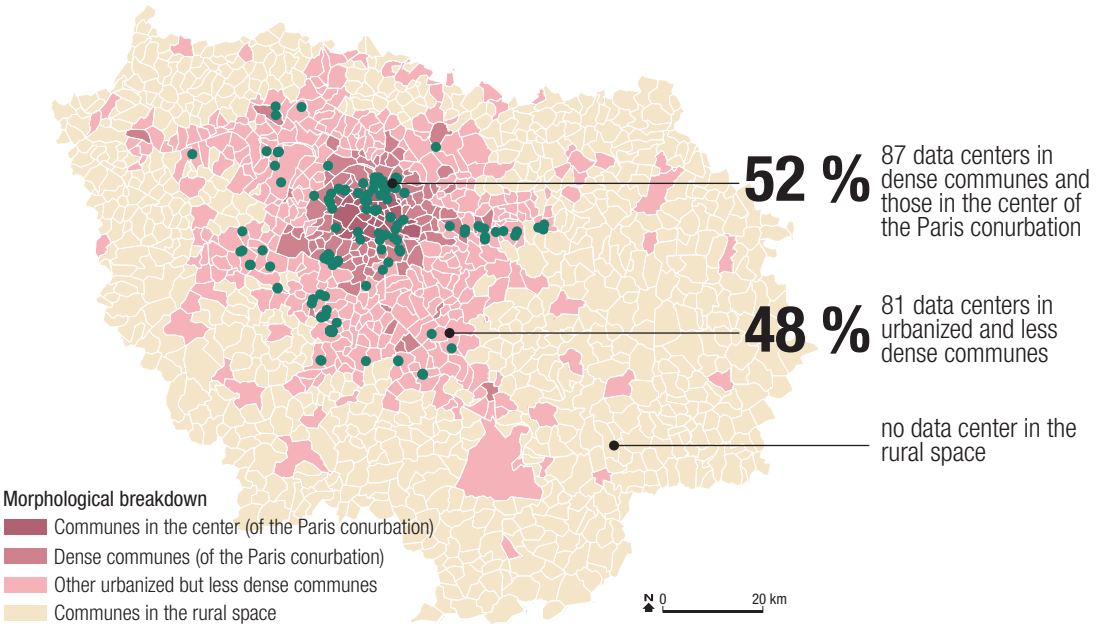
DATA CENTERS AND NETWORKS (ELECTRICITY AND INTERNET)



Being informed to act: the data base of data centers in Île-de-France[38]

In April 2023, the database (BDD) of L'Institut Paris Region counted 168 data centers[39] in Île- de-France on 115 sites (land units). It includes colocation and cloud (Data4, CyrusOne, Telehouse, Scaleway, Equinix, Interxion, OVH...), research (universities, laboratories), public data processing (Ministry of the Economy), bank and large company (Atos, EDF, IBM...) and telecom (SFR, Bouygues, Orange...) data centers. A data center in our BDD can therefore correspond to a dedicated building in the same way as a ground floor of a mixed building. The size of these installations varies depending on their typologies and how they are integrated into their sites (see diagrams below). The BDD includes data centers in operation and those in the project stage, but also those that are closed and abandoned projects.
All these installation are located in a radius of 40 kilometers around Paris. Divided and disseminated across the conurbation, they are located in very diverse urban contexts.

According to an analysis of the morphology of the conurbation[40] and the data base, these 168 data centers in the Paris region are divided as follows[41]:

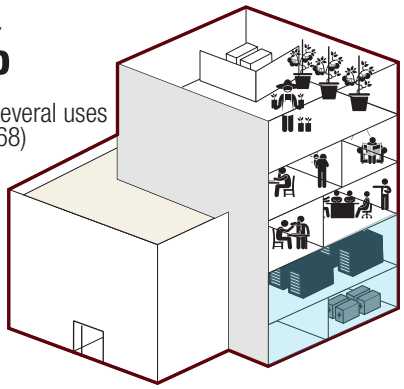


38. What is counted as a data center in our database? What are the data that we have? See the annex for more information on the origin of the database and the methodology.
39. 117 data centers in confirmed operation, 32 in the project stage or under construction, 12 for which the operating condition remains to be confirmed (no certainty if still in activity or not), 7 closed/upcoming closing/ abandoned project sites. The DBB of L'Institut Paris Region counts, in reality, 175 points, 7 of which have been excluded from this work due to a lack of information. They are principally projects that have barely been defined at this stage.
40. 2017 morphological division of L'Institut Paris Region.
41. 23 data centers are located in a commune in the center of the Paris conurbation (PC), 64 in a dense commune of the PC and 34 in a mostly urbanized commune of the PC. 41 are located in another commune of the PC and 6 in the principal communes of other conurbations.

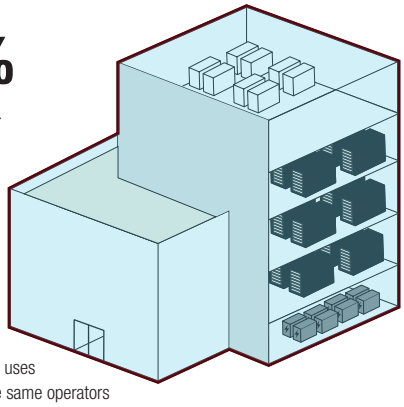
As mentioned above, the Paris region data centers were installed in buildings that are distinguished by their initial purpose and their programming:

· only a quarter of Paris region data centers in buildings with mixed programming...

27 %
in buildings
that house several uses
(46 out of 168)



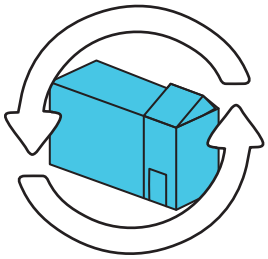
73 %
in buildings
reserved for
this use*
(122 out
of 168)



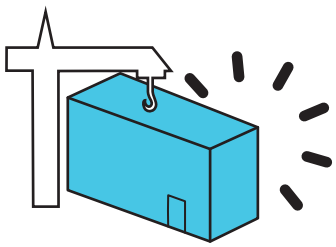
*apart from
internal attached uses
like offices of the same operators

· more buildings transformed than specialized (newly built for data center usage)...

55 %
in transformed
buildings
(92 out of 168)



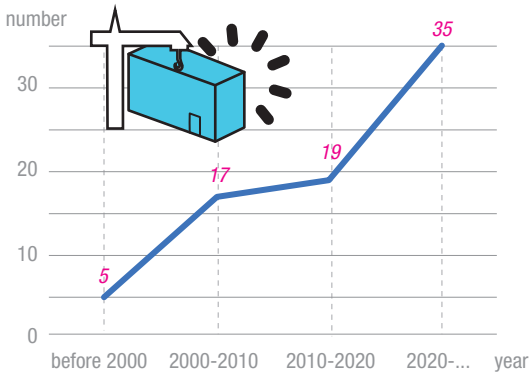
45 %
in specialized
buildings or
purpose-built
data centers
(76 sur 168)



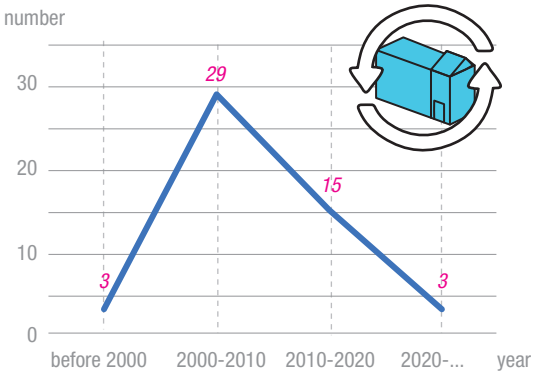
Most of the buildings that are being or were built intentionally to house the data center are exclusively or mostly used as a data center.[45] One exception is, for example, the data center of the City of Paris and the Paris hospital system. Delivered in 2019, the *La Chapelle internationale* building hosts a data center among other activities.

The sector's growth, cited in the preceding part, is also confirmed by the observation of buildings hosting data centers with, notably, the focus on the date of construction for specialized buildings (created to incorporate the data center, see explanation below) and the date when the data center was brought online for the transformed buildings:

Construction of data centers in specialized buildings



Data centers brought on line in transformed buildings*



** only 50 of the 92 data centers in transformed buildings taken into account due to lack of information on the others.*

Source : L'Institut Paris Region, 2023

42. Note: The managers or owners of the site often house some of their offices in the same buildings as the data centers. Through lack of knowledge on the share that these offices represent, these cases are only rarely taken into account in our database and the buildings are considered reserved for this use.

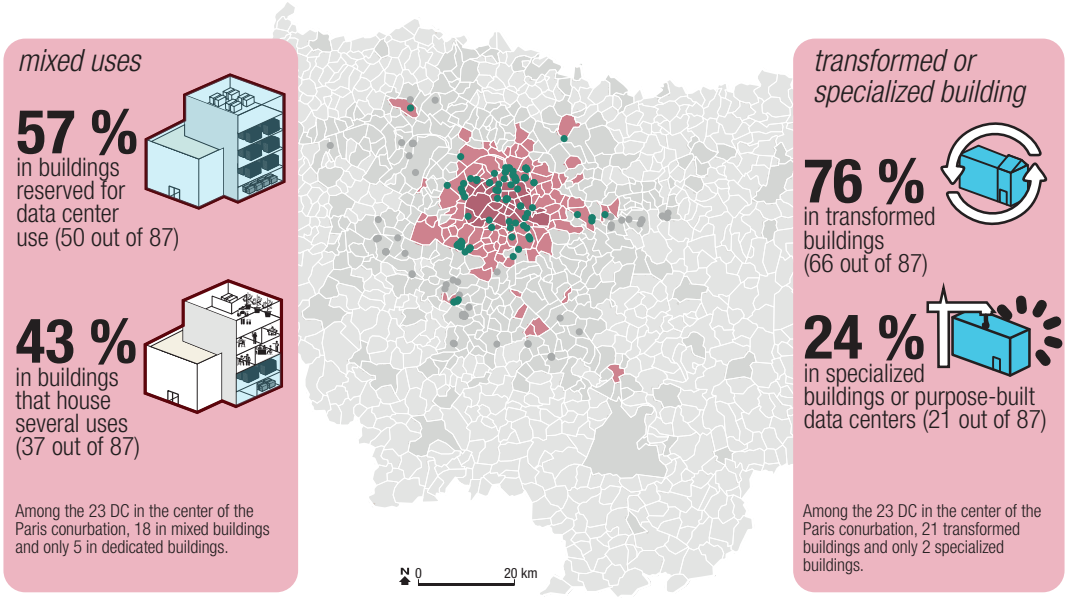
This analysis shows a strong growth among the data centers in specialized buildings, while the service startup of data centers in transformed building is reduced. It was much stronger between 2000 and 2010 and the 2020 decade is only at its beginnings. **The sector is therefore moving in the opposite direction of a recycling, transformation and reconditioning dynamic of existing buildings, although it had been a pioneer at its beginnings.**

In terms of the spatial breakdown of data centers, two dynamics can be observed, **clustering and dissemination.**
Clustering, meaning a group of data centers in certain sectors, can concern:

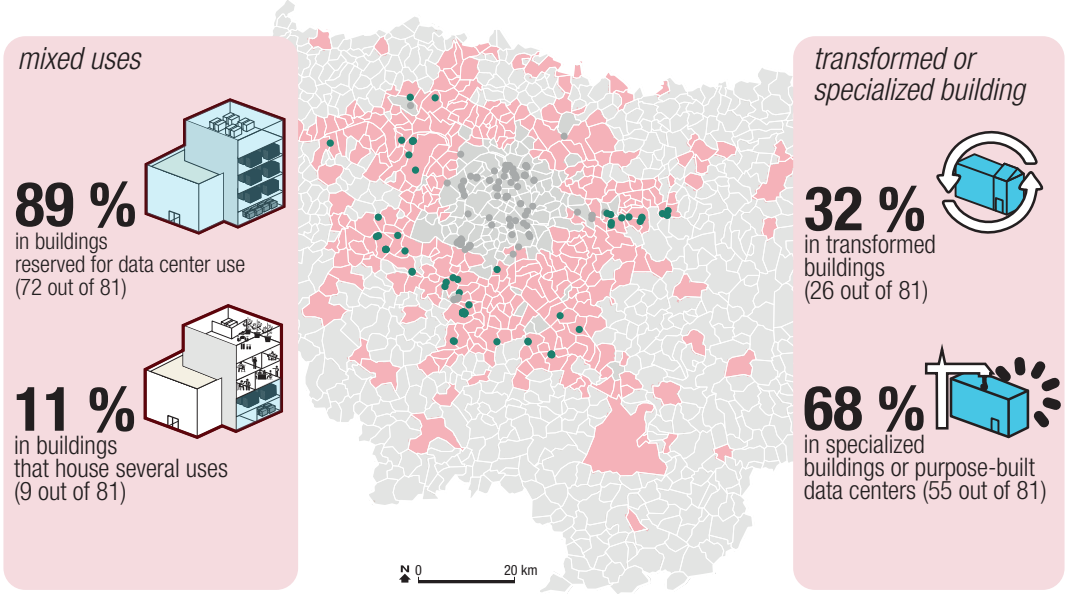
- A data center accumulation on the same site (a land unit), most often of a sole operator (extreme case: Data4 in Marcoussis, which will eventually group 23 buildings, 10 of which are in the project stage).

CROSSING BETWEEN THE CONURBATION'S MORPHOLOGY AND THE TYPES OF BUILDINGS

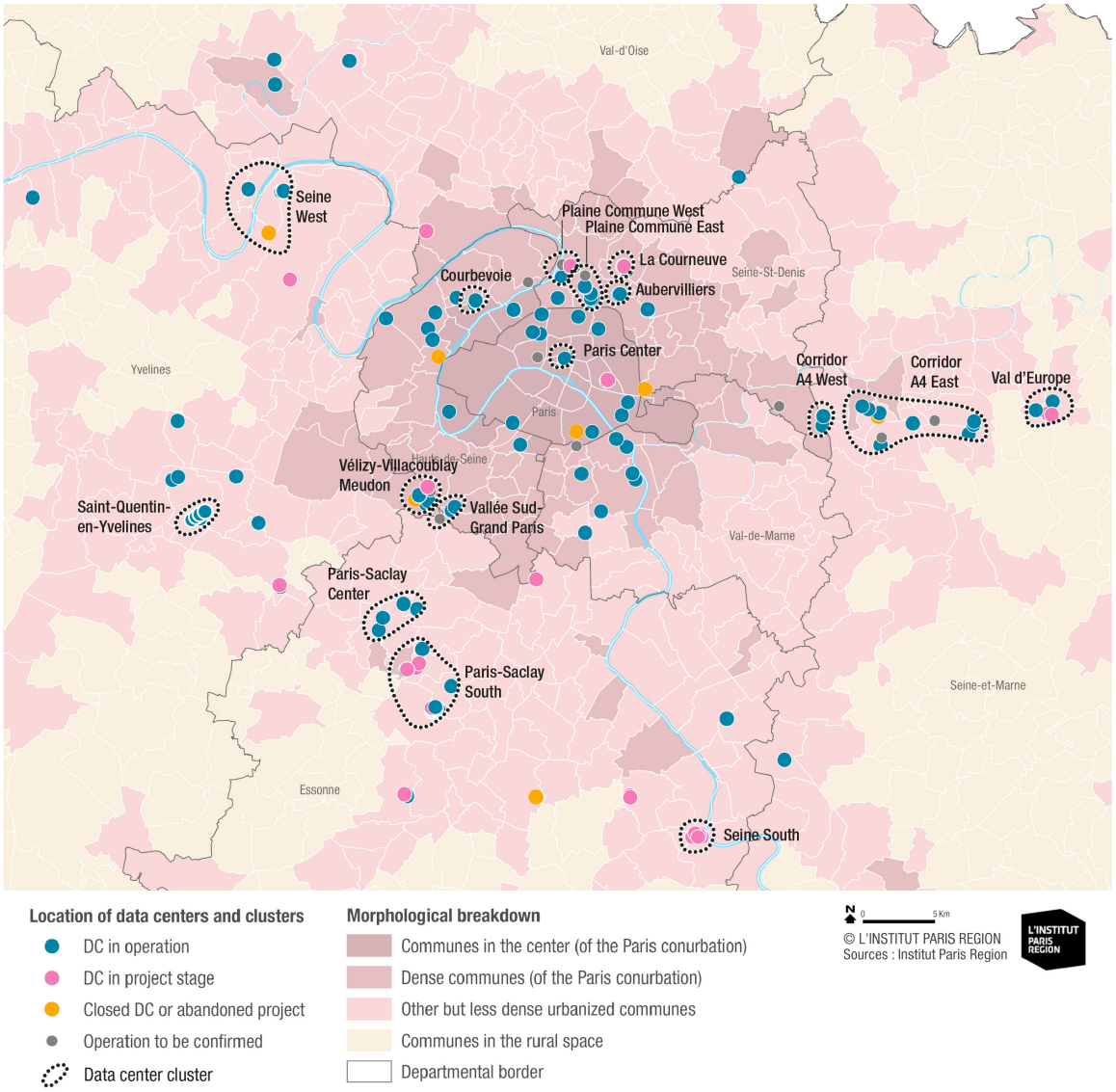
In dense communes and those in the center of the Paris conurbation...



In the other urbanized and less dense communes...



TERRITORIAL BREAKDOWN OF DATA CENTERS



- A group of data centers on distinct land units, but in proximity. Most often of several operators, one of the operators can sometimes have several buildings in the same sector.

Île-de-France has **16 clusters of data centers,**[43] which are, from west to east (see above): Saint-Quentin-en-Yvelines, Seine-West, Paris- Saclay Center, Paris-Saclay South, Vélizy-Villacoublay, Meudon, Vallée Sud-Grand Paris, Courbevoie, Plaine Commune West, Plaine Commune East, Paris Center, Aubervilliers, La Courneuve, Corridor A4 West, Seine South, Corridor A4 East and Val d'Europe.

While the clustering effect seems to be confirmed in île-de-France, these are the two trends that are continuing in parallel, according to the analyses of recent cases and projects underway.

In the future, the evolution and consolidation of existing clusters and the creation of new clusters will depend on both market dynamics as well as a possible regional development strategy for data centers drawn up and initiated by the public actors.

43. Definition of the cluster according to the spatial request. The distance between two data centers is 1 km in the center of the conurbation and 3 km outside of this zone. The minimum number of a cluster is three data centers.

Identifying spatial and programming criteria to establish a spatial typology

Sketched out in Part 1 of this report, certain criteria of a spatial and programming order make it possible to establish a typology of data centers. We will use here the same numbering as on page 16 and detail these criteria:

15. **The global location in the conurbation:** in the communes in the heart of the metropolis, the dense conurbation, the mostly urbanized space, the outskirts of urbanization...

16. The local urban environment: **the more or less dense urban fabrics.**

17. **Land units ("sites"):** large or contaied (blocks with contiguous ownership, composed of one plot or a group of plots).

18. **The location or not in a data center cluster.**

19. **The programming of the building:**
    - **Building with a mixed programming:** building housing several activities (offices, companies, housing), including that of the data center in a part of the building. Concerns transformed buildings (frequent) or new constructions (very rare).
      Synonyms: shared building, integrated data center.
    - **Building reserved (for the data center):** building exclusively or mostly serves for data center use. Can be found in specialized or transformed buildings. Île-de-France has many examples of buildings that are transformed and reserved for the DC. (Telecom building are likely to also contain offices. Due to lack of information, we have classified them as reserved buildings.)
      Synonyms: building dedicated to the data center, for exclusive use.

20. **Initial purpose of the host building:**
    - **Transformed building:** existing building transformed to host the data center. DC use was not considered when the building was designed. Construction date of the building differs from the date when the DC went online. Can concern a building with mixed or reserved programming.
      Synonyms: old, existing, reused, reconditioned building, rehabilitated or renewed building, inserted data center.
    - **Specialized building:** DC hosting considered from the building's design. Construction date of the building the same as the date when the DC goes online. This type also called "new construction," but construction can date back to the late 1990s/ early 2000s. Only very rarely concerns buildings with mixed programming.
      Synonyms: purpose-built, new construction, new building.

21. **The installation process of data centers** (see opposite):
- In the existing (transformed building)
  - **Insertion;**
  - **Renewal of the existing building;**
- In new construction (specialized building);
  - **Renewal of the site;**
  - **Densification;**
  - **Land artificialization.**

22. **Integration of the data center into its site** (see opposite)
    - **Building occupying the entire site**
    - **In a building on a larger site**
    - **data center on a very large site (private campus type)**

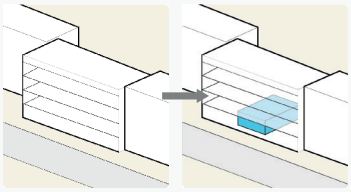
23. **Land-use ratio that, in liaison with the last point,** calculates the ratio of the land of which is sited the building that hosts the data center to the whole land unit.

EXPLANATION OF TWO SPATIAL CRITERIA

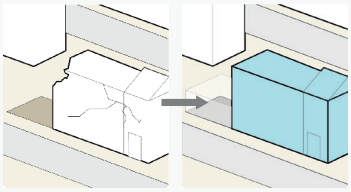
21. The data center installation processes

The transformed building

Insertion
Siting of a data center in part of an existing building (often commercial or technical premises or occupation of a whole building without modification of the façade, etc.)

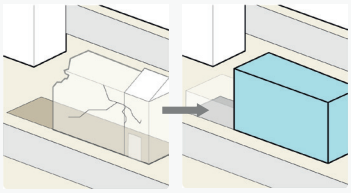


Renewal of the building
Transformation of an existing building (former commercial telecom or abandoned industrial sites, warehouses hangars…), keeping the façade elements, structure…

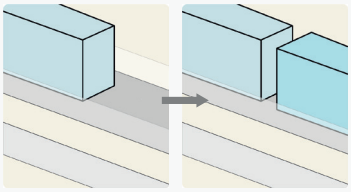


The new and specialized building

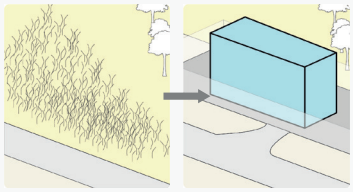
Renewal of the site
New construction on artificialized land (former commercial, telecom or abandoned industrial sites, warehouses, hangars...). Demolition of former building but preservation of some details of the building or former site (façade, roof, building form, etc.).



Densification
New installation of a data center on a site already occupied by a data center.



Artificialization
New installation of a data center on a site once classified as natural land, forest or farmland. Sometimes in continuity with existing data centers.



Other linked phenomena

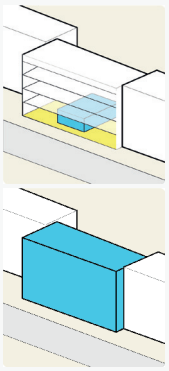
Intensification
Renewal and densification of IT equipment *in situ*.

Disappearence
Shutdown of data center's activity and conversion of building or site for other uses, sometimes even housing (Paris region examples in Vélizy-Villacoublay and Lognes).

22. Insertion of the data center into its site

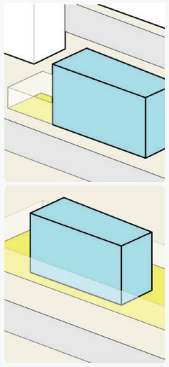
Data center or host building occupies the entire land unit
Data center occupying a technical room of mixed building (with housing, offices, businesses) or a dedicated building. Often, the technical equipment is hidden inside the building, in the basement or on the roof. Generally in mixed and dense fabrics (center of the conurbation) or on a mixed island. Some cases occupy office buildings in less dense fabrics. One or more façades face the public space, with more or less visibility on the use of the data center.

Examples: the data center, in blue, occupies part of a building (top) or a whole building (bottom). In both cases, the building occupies the whole land unit. Generally this concerns a contained site (definition on the following page).



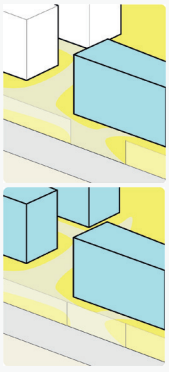
Data center or host building occupies larger land unit
Site comprised of more or less considerable external part, in which part of the functional (parking, delivery, storage) and technical (backup generators, transformers) elements are externalized. External parts fenced/walled off and under surveillance. Often connected to the size of the site, one or more façades face the public space, in other cases, building is distanced from the site's boundary wall. Certain operators (colocation actors) display their name on the site, but visibility on the site's use generally remains limited.

Examples: the buildings with the data center are located on sites that are slightly larger than the building (top) or more (bottom). This then concerns a **contained site** (top) or a **large site** (bottom).



Data center on very large land unit (private campus type)
Data center occupying reserved building on a private campus (ex.: company or private business parks) with several buildings (often same architecture) of a single or several groups.
If a company park, technical equipment often located inside the building and only certain pieces of functional equipment are externalized. Company parks often open to the public. Building accessible from several sides. If data center campus, a large part of the functional (parking, delivery, storage) and technical (backup generators, transformers) elementss are pooled and located outside. Fenced/walled off sites under surveillance, very opaque and placed at a distance.

Examples: the buildings with the data center are located on large sites with buildings and other types of uses (top) or dedicated to data centers (bottom). This generally concerns a **large site**. Land reserves within the site are often available. Very infrequently, the site occupation rate is so high that it is a question of a **contained site**.



site (land unit) | building without data center | room or building exclusive to data center | building housing a data center (exclusive ou mixed)

Source : L'Institut Paris Region

2.2 ESTABLISHING A TYPOLOGY OF DATA CENTERS IN ÎLE-DE-FRANCE

We propose a typology based on principally spatial criteria:

- **The urban environment: more or less dense urban fabrics;**
- **Land units, or sites, either large or contained[44];**
- **The initial purpose of the host building: specialized building (hosting of DC considered from the building's creation) or transformed building (transformed later to house the data center).**

Instead of a classification by activity center or positioning in the digital ecosystem (which seems difficult to us to use for certain data centers, operators or customers),[45] our typology employs a spatial approach that permits us to classify all the data centers in the Paris region. Based on the criteria cited above, we will better understand and be able to describe the different installation processes and siting strategies used in the Paris metropolis. For this work, only the data centers in our database were analyzed. This typology is therefore specific to Île-de-France, making it possible to understand their diversity. Certain data centers are difficult to classify and could correspond to several types. Within a family of data centers, sites can be more or less heterogeneous, notably in terms of size, type of siting and construction date.

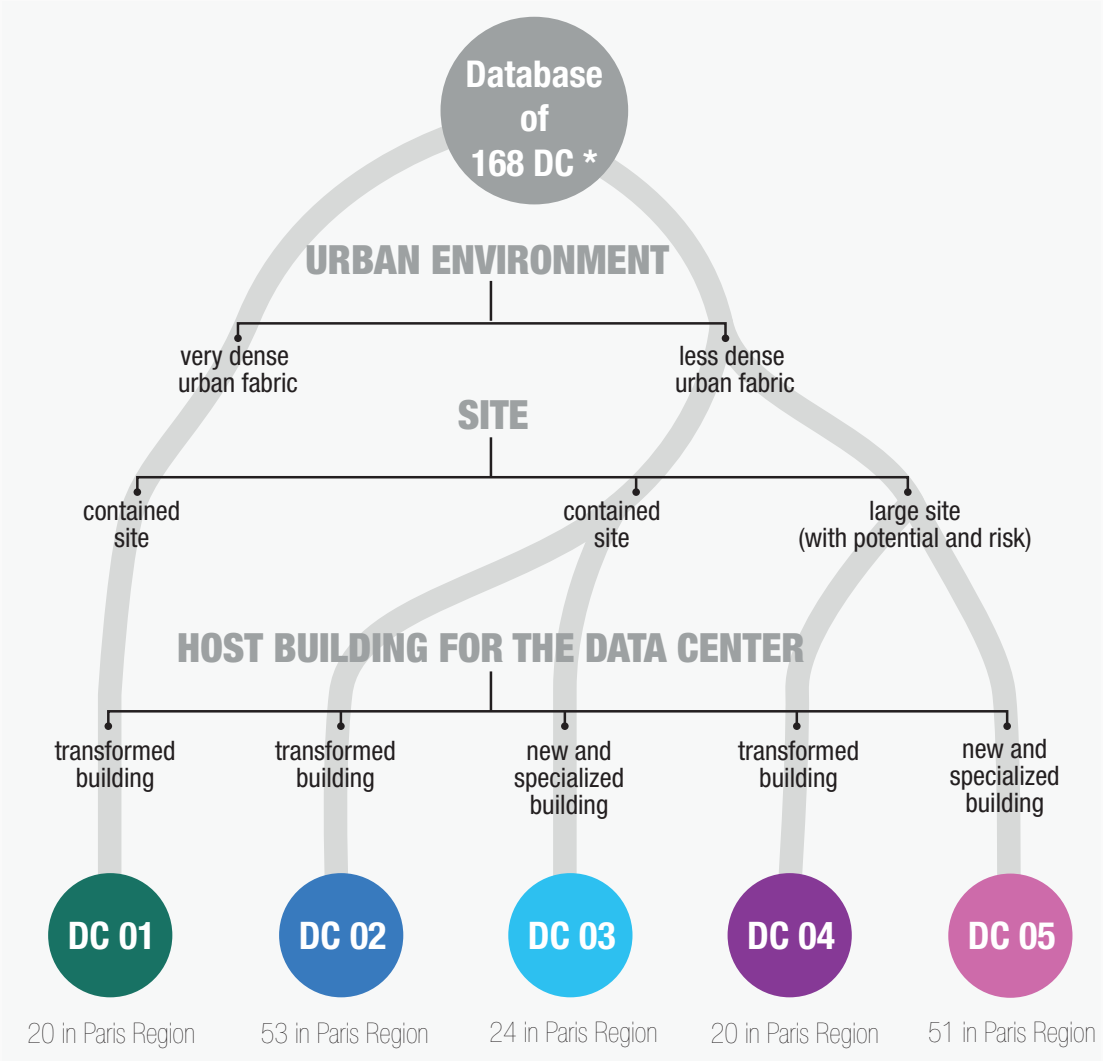
On the following pages, each of the five types of data centers is detailed on a double page. Following the history of different data centers in Île-de-France that is often that of a reuse of existing buildings, we have estimated, for each of the types, a potential for evolving toward new DC or other uses. For each type, an average land use percentage illustrates the intensity of the occupation of the space (ratio of buildings housing data centers on their sites). Consequently, the DC 01 type – "The infiltrated data center" – occupies on average 70% of its land unit, while the DC 05 types – "The new data center on the metropolitan outskirts" only occupies 18%...

This typology will, if necessary, make it possible to nuance and adapt, in the field, the proposals formulated in Part 4 of this report.

44 **Contained site:** generally small units with little additional development potential (except by purchasing neighboring plots and/or demolition of buildings), already heavily built, sometimes by other data centers. Densification phenomenon within a land unit by new constructions (in height) nevertheless recurring.
Large site (with potential and risk): land unit with development potential, for example, on vacant or abandoned land within the unit, or contiguous to it. But this potential concerns not only the open spaces: as the site is often occupied by a sole owner, the transformation of existing buildings or demolition/new construction can be facilitated. Sometimes unit occupied by several data centers (ex.: business park), without the landowner necessarily being the data center operator. If the data center is already present, future development is even further facilitated.
A large site such as this can then be seen as a potential for site or building renewal or on-site densification. On the other hand, this large site can generate an appetite for future developments. At the risk of consuming natural spaces, farmland and forests inside the perimeter, as can be notably seen for the DC 05 type, detailed later on.

45. Certain observations are notably mentioned at the end of his point.

TYPES OF DATA CENTERS BY SPATIAL CRITERIA



* The L'Institut Paris database of data centers has 175 points. As for projects for which neither architecture nor precise siting was known to us, 7 data centers have been excluded from this typology.

DC 01

DATA CENTER IN A VERY DENSE URBAN FABRIC
ON A CONTAINED SITE AND IN A TRANSFORMED BUILDINGS;
THE INFILTRATED DATA CENTER

This type of data center is inserted into an existing, often historic building, such as former department stores, apartment houses (Foliateam Paris Nation) or office buildings. These buildings show a high degree of adaptability and generally have a sufficiently robust structure to support the weight of the servers. The data center generally only occupies a small part of a collective building, like a story or former technical premises. As a result, the data center's visibility is very limited.

The location in the heart of the metropolis is strategic. Thus, these data centers are found near other data centers and their customers and notably internet hubs.

Urban fabric
Very dense. Outside economic activity zones (or business park) (only exceptions: central Paris and La Défense).

Insertion of the data center into its site
Integrated into a building with mixed programming generally located on a dense block. In rare cases, this data center occupies an entire building dedicated to its use. Generally, all the annex equipment is included in the building.

Installation process
Generally "insertion," rarely in "renewal" (transformation of an entire existing building).

Size*
Only occupying a small part of a large building, this type of data center often occupies an IT area under 1,000 m2. However, a few sites occupy spaces as large as 5,000 m2 IT or a whole building (up to 7,000 m2, for example, Telehouse Voltaire, Paris).

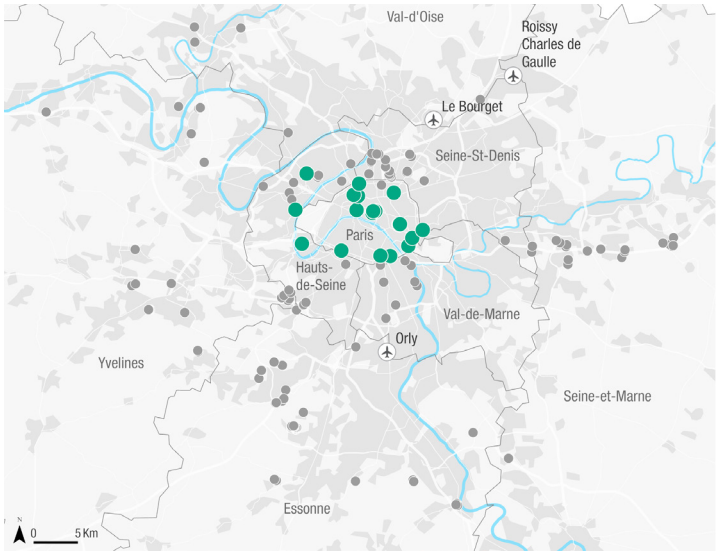
Construction period
Mostly before 1990 (80%) , of which 10 buildings that even date to before 1950. 4 buildings were built between 1990 and 2000.

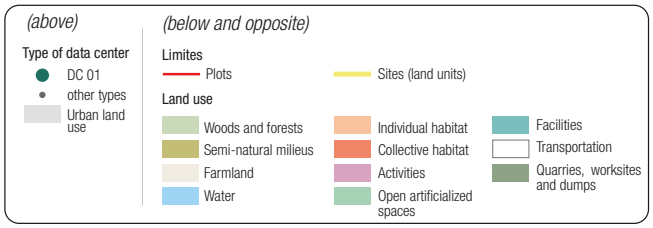
Data center service start-up period
Mostly in the early 2000s, a few more recent cases (2017, 2021).

Building characteristics and landscape impact
Building (houses, offices, businesses) of several stories in a very dense and mixed urban fabric. Building accessible from the public space with at least one façade facing the public space. No fences. However, the use of the data center remains invisible for the public.

Evolution
Very high rate of evolution. Spaces can be reused for a new data center or another activity, as was done in the preceding decades.

* Size: data to be used with caution, due to a lack of information. When the floor area used for the data center or the power (MW) was available, we were able to extrapolate to estimate the IT area. However, for only 70% of our database at least one of the variables (area, IT or MW of power) was known to us.

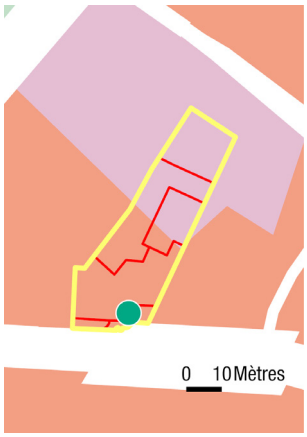




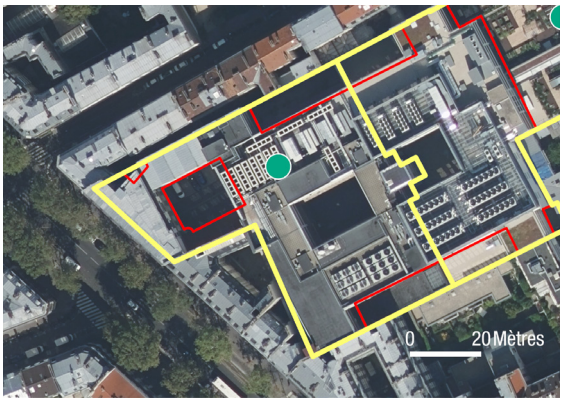
SITE A OVH DC 01 in Paris, 19th arrond.

Since 2008, this data center of the French operator OVHcloud has occupied a floor area of about 3,000 m2, in this transformed building dating to the 1990s that also houses other uses.

Source: L'Institut Paris Region, 2023

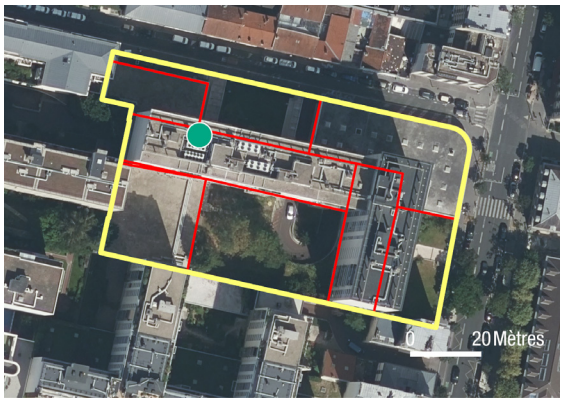


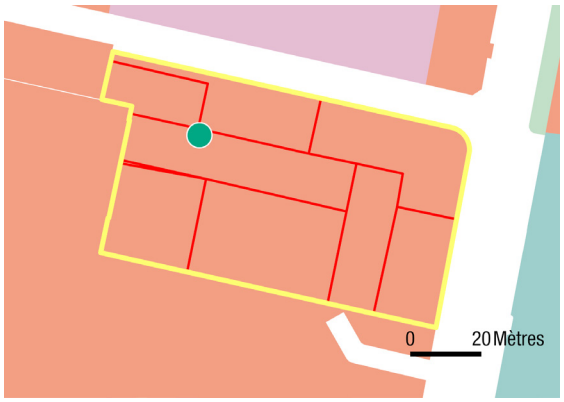
SITE B Telehouse 2 Voltaire in Paris 11th arrond.



With an IT area of 7,000 m2, this Telehouse data center is one of the largest data centers in the heart of the metropolis, occupying a historic building of a department store. In 2021, it opened its extension (TH2) which is located on the same block.
Source: L'Institut Paris Region, 2023

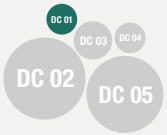
SITE C Foliateam Paris Nation in Paris 12th arrond.





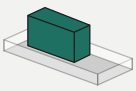
This Foliateam data center is inserted into a 1960s-1970s apartment house, occupying a space with at IT area of about 2,000 m2.
Source: L'Institut Paris Region, 2023

A type of data center little represented…



12 %
of data centers in the Paris region (20 out of 168)

Dense sites…



70 %
land take coefficient on average (density of the plot)

Buildings almost exclusively concerned by mixed uses

1 out of 10
of this type reserved for data center use

DC 02

DATA CENTER IN A LESS DENSE URBAN FABRIC,
ON A CONTAINED SITE AND IN A TRANSFORMED BUILDING

THE CONVERTED DATA CENTER IN AN ACTIVITY ZONE

This type of data center is inserted in an existing building of very different typologies (diverse small buildings, transformed former hangars or reused telecom sites…), very frequently in economic activity zones. The plots are often very contained by a relatively dense environment and the expansion potential is very limited. This type of data center is sometimes associated with the DC 03 type. Visibility on the data center's use is generally very limited, and it could be taken for buildings with other uses like hangars, company headquarters or offices. The sites are usually fenced-in and secured.

The location in the metropolis: mainly in the communes in the center of the Paris conurbation and in dense communes (74%), a part is located in other communes in the Paris conurbation.

Urban fabric
Not very dense to relatively dense. Located in economic activity zones (some cases in facility or discontinued activity areas).

Insertion of the data center into its site
Mostly occupies a building dedicated to this use, sometimes also a mixed building, on a plot that is larger than the built portion's footprint. The plot sometimes has other smaller buildings and annexes that house generators, transformers, backup generators.

Installation process
In renewal, an existing building (warehouse, logistics, other activity) is transformed into a data center, often with changes in the building's appearance.

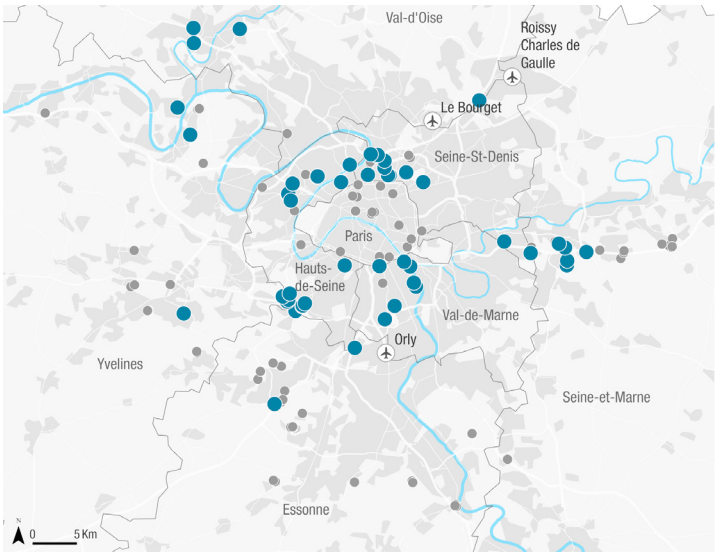
Size
Type of data center very heterogeneous in form and size. Often with IT areas above 2,000 m2, even 4,000 m2, with a few exceptions larger than 10,000 m2.

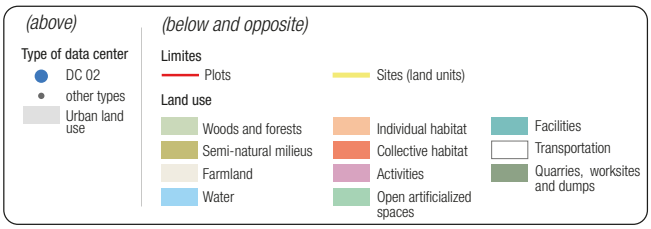
Construction period
Generally before 1990 (74%), the rest until the early 2000s.

Data center service start-up period
When known between 2000 and 2010, a few more recent examples. One project underway.

Building characteristics and landscape impact
Former office buildings, former hangars, former telecom buildings (sites dedicated to data center use) and office buildings that have several companies (sites not dedicated to data center use).
Requalification of the façade, preservation of the emblematic parts of the building (form, architectural style) mean that the building is well-integrated into the former requalified industrial fabric. Issue of securing the site (fences, surveillance cameras) damages a quality integration into the landscape. Generally no direct access to the public space.

Evolution
Average. For reused buildings, reinvestment for another use can be imagined (offices, logistics, e-commerce), but the real feasibility is unknown. Probably requires the construction of a new building on the same plot for more complex projects.

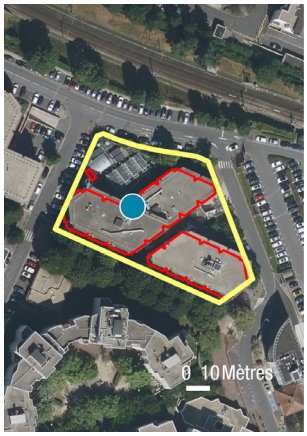


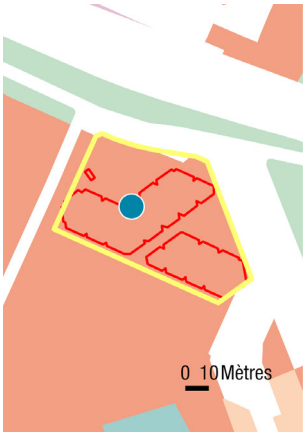


SITE A Euclyde Data Centers DC6 IDF in Lognes (77)

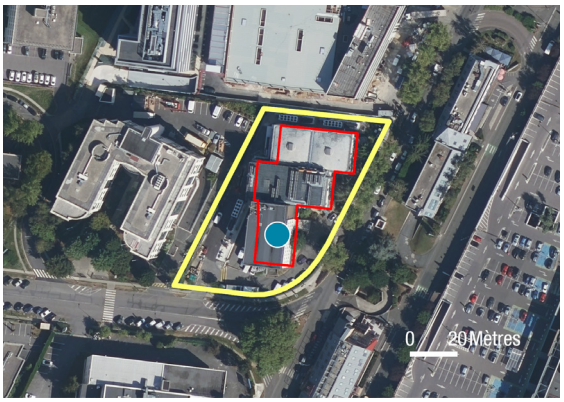
Occupying a former office building built in 1986, the site was initially transformed into a data center for HSBC. It is the Euclyde group that operates this site today. It has a total area of 5,500 m2 and an IT area of about 2,200 m2 divided among three floors.

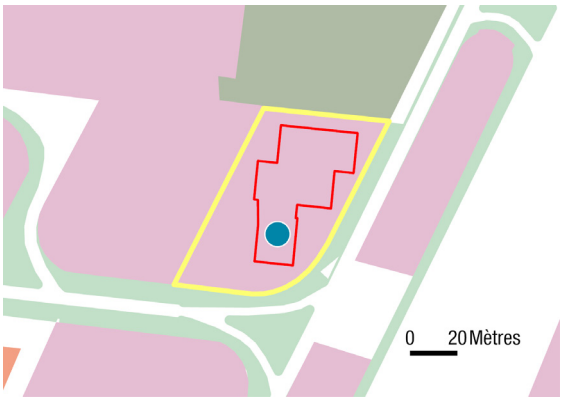
Source: L'Institut Paris Region, 2023





SITE B DataBank FR3 in Vélizy-Villacoublay (78)

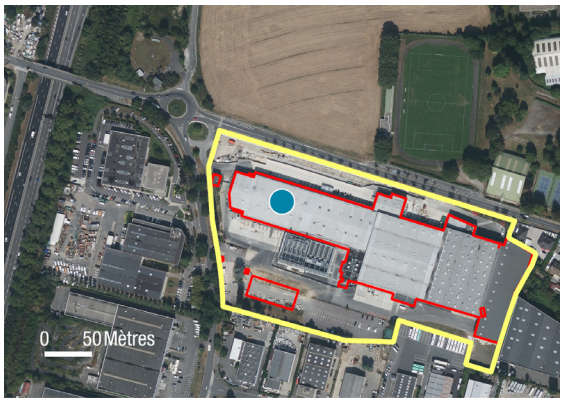


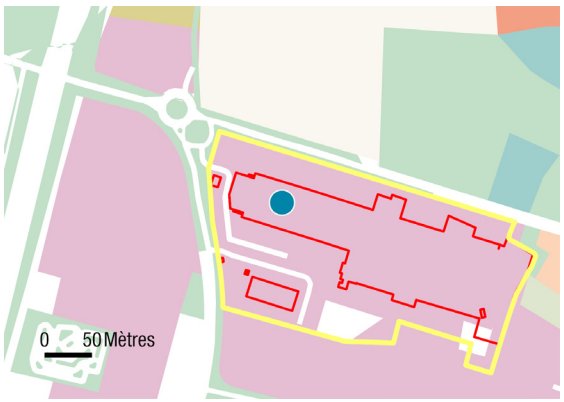


Installed in a former 1987 telecom building, this site was transformed into a data center in 2007, with an IT area of 3,250 m2 divided among three stories.

Source: L'Institut Paris Region, 2023

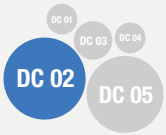
SITE C CyrusOne (Project) in Wissous (91)





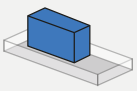
This CyrusOne project currently underway concerns the transformation of a former logistics hangar to house several data halls inside the building. It should have, in the end, a power of 83 MW, which would make it one of the largest data centers in France. It will be totally dedicated to AWS.
Source: L'Institut Paris Region, 2023

The most frequent type of data center in Île-de-France…



32 %
of data centers in the Paris region (53 out of 168)

Relatively dense sites…



48 %
land take coefficient on average (density of the plot)

Buildings rarely concerned by mixed uses

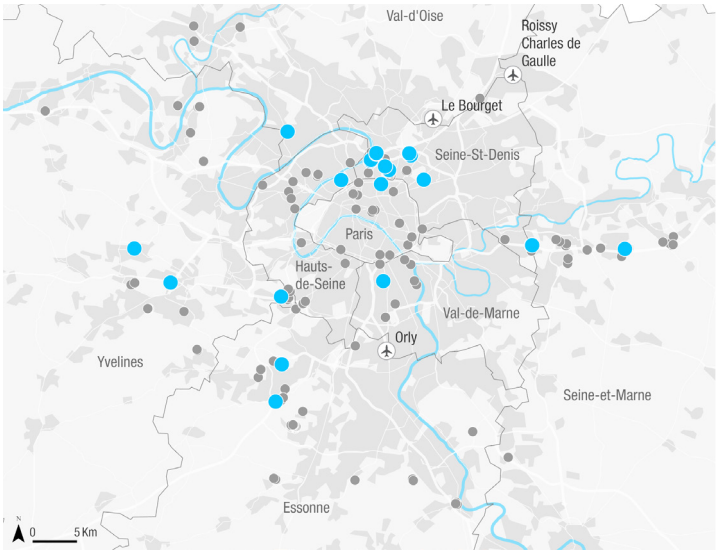
7 out of 10
buildings of this type reserved for data center use

DC 03

DATA CENTER IN A LESS DENSE URBAN FABRIC,
ON A CONTAINED SITE AND IN A NEW AND SPECIALIZED BUILDING:
THE NEW AND OPTIMIZED DATA CENTER

This type of data center occupies (totally or partially) new or purpose-built buildings. Most of these buildings are dedicated to data center use. Through their idealized design for this use, they are genuine ultra-high-performance digital factories that often house several data halls (IT rooms) opened as the building fills up. The urban fabrics are similar to the DC 02 type, within a previously industrial economic activity zone equipped with warehouses and logistics zones and on contained plots. Certain examples show a process of densification of these plots already occupied by a data center by the same operator. This group contains several projects and four buildings with mixed programming (research, offices and other activities) in which the use of the data center was taken into account when the building was designed.

The location in the metropolis: mainly in the communes in the center of the Paris conurbation and in dense communes, a part is located in other communes in the Paris conurbation.



(above)

Type of data center
- DC 03
- other types
- Urban land use

(below and opposite)

Limites
- Plots
- Sites (land units)

Land use
- Woods and forests
- Semi-natural milieus
- Farmland
- Water
- Individual habitat
- Collective habitat
- Activities
- Open artificialized spaces
- Facilities
- Transportation
- Quarries, worksites and dumps

Urban fabric
Not very dense to relatively dense. Located in economic activity zones (exceptions in facility or discontinued activity areas).

Insertion of the data center into its site
Mostly occupies a building dedicated to this use on a plot that is larger than the built portion's footprint. The plot sometimes has other smaller buildings and annexes that house generators, transformers, backup generators.

Installation process
In new construction, these data centers are often examples or urban renewal on former industrial wasteland or examples of densification of plots already occupied by a data center. This rarely concerns land artificialization.

Size
Very heterogeneous, certain data centers reach IT areas of about 10,000 m2.

Construction period
Almost all these constructions were built after 2000. 14 of them were even built after 2010, of which 8 were delivered in 2021-2022 or near this period.

Data center service start-up period
The service start-up of this type globally corresponds to the building's construction date.

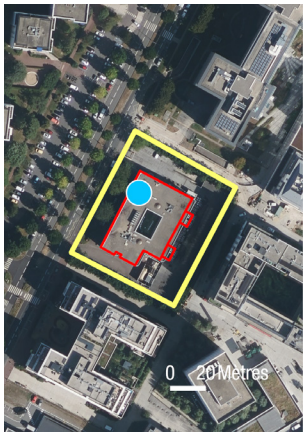
Building characteristics and landscape impact
The building's typology is very similar to the DC 02 type, which is inserted into comparable fabrics, like requalified industrial sites. The architecture is also often similar. A quality architectural treatment is frequently proposed (façade, typology). Issue of the site's security (fences, surveillance cameras) damages the quality of the integration into the landscape. A direct access between the building and the public space is rarely purposed. On the plots already occupied by another data center, this type is often restricted by a multi-story construction.

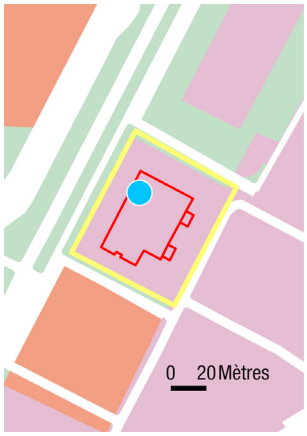
Evolution
Limited. Low reuse potential of this specialized building for another use. Probably requires new construction within the boundaries of the plot. If a recent data center, probably better reinvestment potential for data center use.

SITE A Odigo in Vélizy-Villacoublay (78)

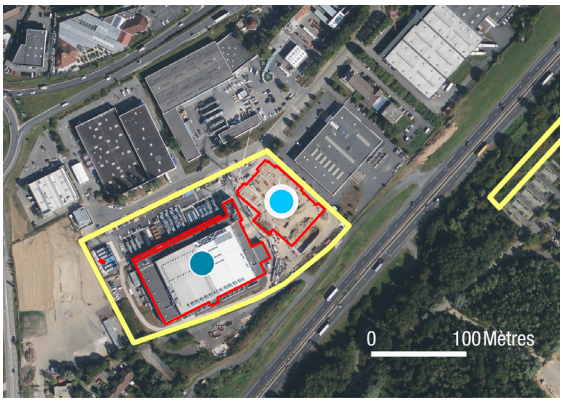
Built and put online in the early 2000s, this Odigo (ex-Prosodie) data center reserved for DC use, was installed in an activity zone that is now undergoing total mutation. The data center will close to make way for 150 housing units.

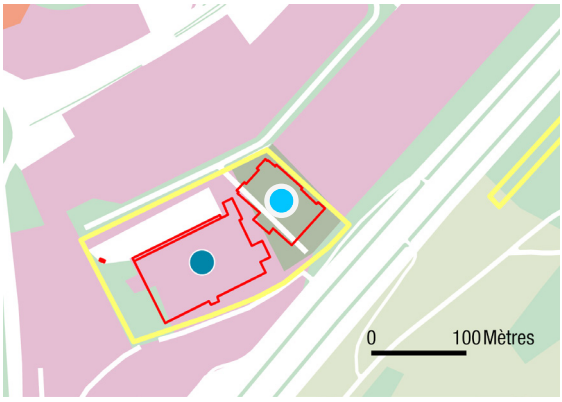
Source: L'Institut Paris Region, 2023





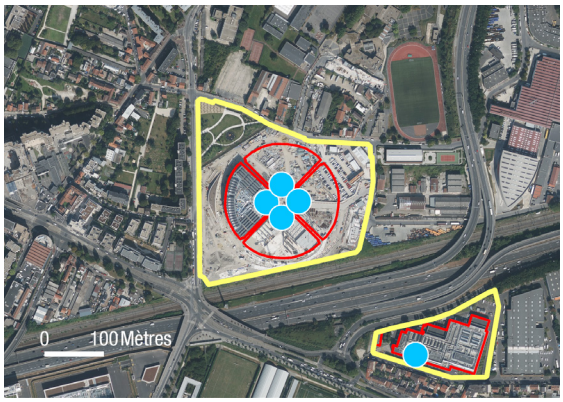
SITE B Colt Paris SW DH10+ in Les Ulis (91)

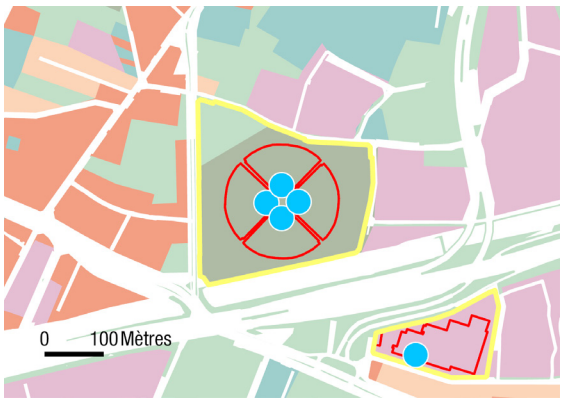




Built in 2022, this new Colt Technology Services data center (light blue dot) is installed on a plot that has already been invested by Colt Paris South West Data Centre, which itself concerned the successive transformation of a logistics warehouse in the 2000s.
Source: L'Institut Paris Region, 2023

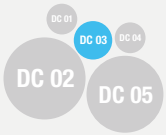
SITE C Digital Realty PAR 8-11 in La Courneuve (93)





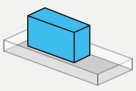
The opening of these new Digital Reality (Interxion) data centers on a former aeronautics site was done in stages in late 2021. With a maximum of 40,000 m2 of dedicated space in the end and a network connection of 130 MW, this site will be one of the largest in France.
Source: L'Institut Paris Region, 2023

A type of data center below the average…



14 %
of data centers in the Paris region (24 out of 168))

Not very dense sites…



44 %
land take coefficient on average (density of the plot)

Buildings rarely concerned by mixed uses

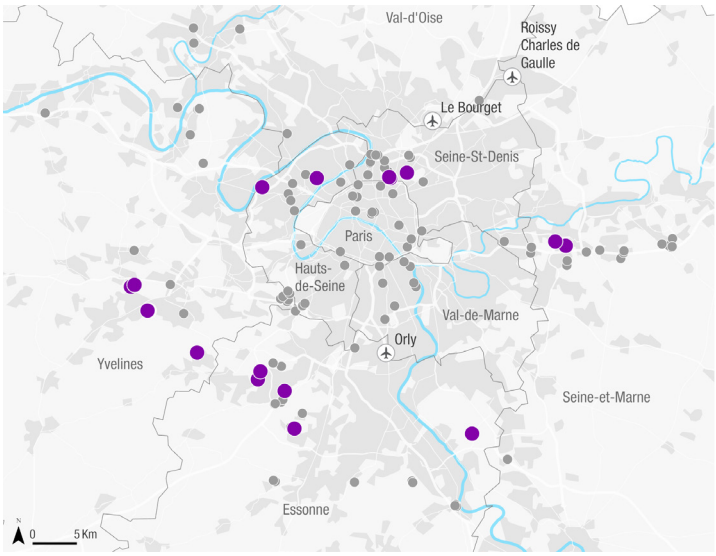
5 out of 6
buildings of this type reserved for data center use

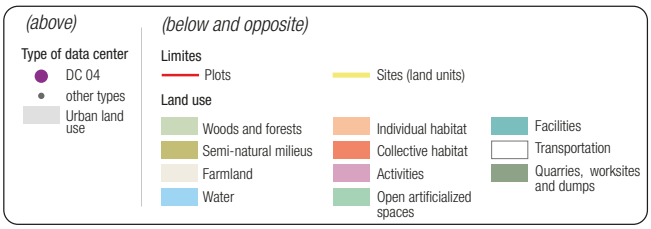
DC 04

DATA CENTER IN A LESS DENSE URBAN FABRIC,
ON A LARGE SITE AND IN A TRANSFORMED BUILDING:
THE CONVERTED AND EXTENDIBLE DATA CENTER

This type of data center is inserted into an existing building of very different typologies, often located on private campuses having a sole manager or in company parks in economic activity zones. The plots are often very large and the expansion potential relatively good. Visibility on the data center use generally remains very limited. The sites are usually fenced-in and secured.

The location in the metropolis: mainly in less dense communes of the Paris conurbation and communes outside this conurbation.





Urban fabric
Not very dense. Located in economic activity sectors and research sites (university campuses).

Insertion of the data center into its site
Most of the time occupies a building dedicated to this use on a plot that is much larger than the built portion's footprint. The plot often has other smaller buildings and annexes that house generators, transformers, backup generators.

Installation process
In renewal, an existing building (warehouse, logistics, research, other activity) is transformed into a data center.

Size
Average, this type of data center rarely exceeds 5,000 m2 of IT area (lack of sufficient quantity of representative information).

Construction period
65% before 1990, 35% between 1990 and 2010.

Data center service start-up period
Lack of sufficient quantity of representative information.

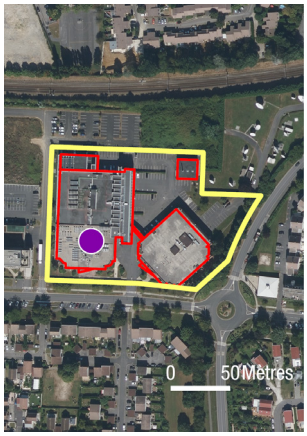
Building characteristics and landscape impact
Former office or telecom buildings, often in private sectors and connected to a company (Alcatel, Société Générale, etc.), the building is generally reused without a great deal of requalification work on the historic building. Issue of securing the site (fences, surveillance camera) damages the quality of the integration into the landscape. No direct access between the building and the public space. Possibility of accessing the building on the estate of the private park.

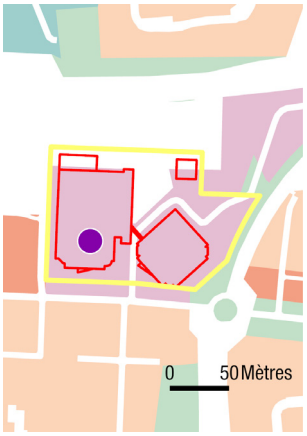
Evolution
Relatively high. For these reused buildings, reinvestment for another use can be imagined (offices, logistics, e-commerce), but the real feasibility is unknown. Probably requires the construction of a new building on the same plot for more complex projects. Large size of land unit makes it possible to imagine other uses after the building is demolished.

SITE A Sungard AS in Lognes (77)

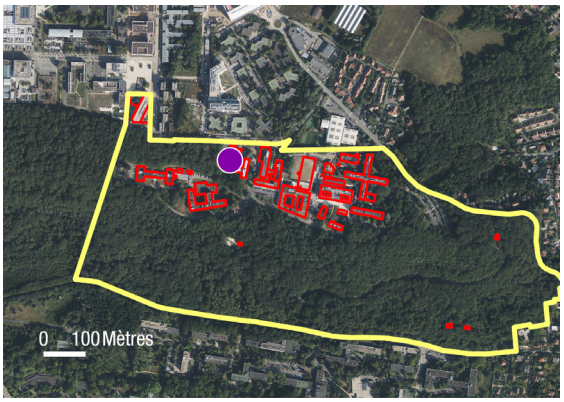
This Sungard Availability Services site occupies two buildings built in the 1980s-1990s. Its floor area is about 14,000 m2. With its hedges and fences, low walls and brick façades, this data center is better inserted into its environment than others.

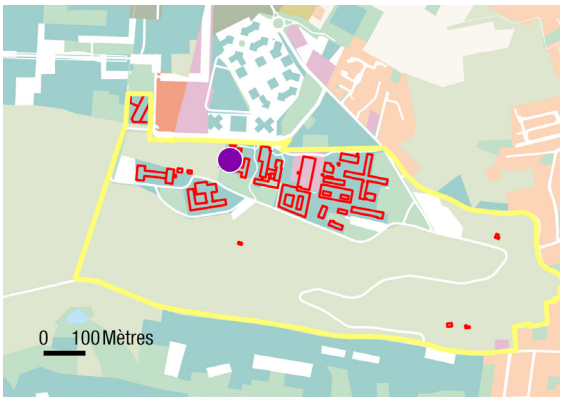
Source: L'Institut Paris Region, 2023





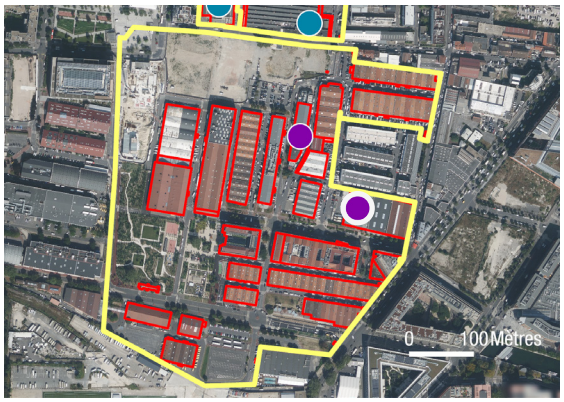
SITE B CNRS - IDRIS in Orsay (91)

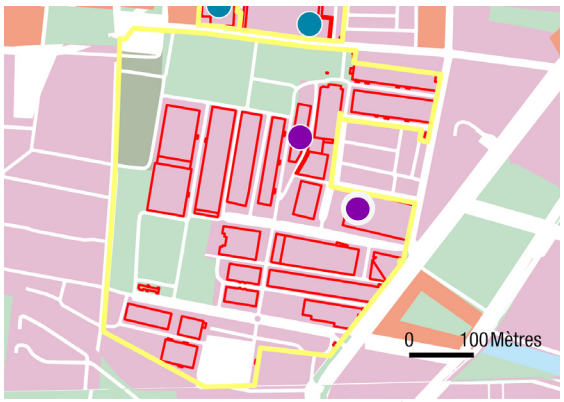




This data center of the Institut du Développement et des Ressources en Informatique Scientifique occupies a multi-use research building. The new supercalculator Jean Zay has been housed on this site since 2020.
Source: L'Institut Paris Region, 2023

SITE C Digital Realty PAR1 in Aubervilliers (93)



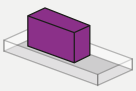


First Interxion (now Digital Reality) data center in Île-de-France, PAR1 was inserted into a former hangar built in the late 1960s, together with other functions. With a floor area of 2,250 m2, it is one of the smallest sites of the group, which will soon have 13 in the Paris region.
Source: L'Institut Paris Region, 2023

A type of data center little represented…

12 %
of data centers in the Paris region (20 out of 168)

Not very dense sites…



35 %
land take coefficient on average (density of the plot)

Buildings rarely concerned by mixed uses

5 out of 6
buildings of this type reserved for data center use

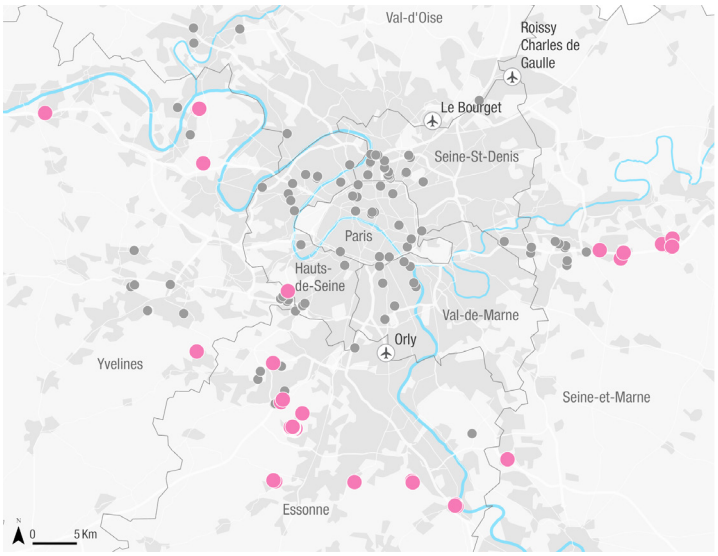
DC 05

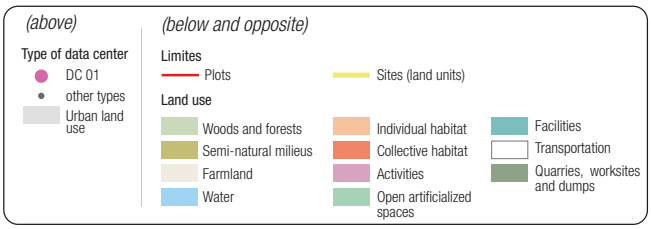
DATA CENTER IN A LESS DENSE URBAN FABRIC,
ON A LARGE SITE IN A NEW AND SPECIALIZED BUILDING:

THE DATA CENTER ON THE METROPOLITAN OUTSKIRTS

This type of data center occupies new or purpose-built buildings. Most of these buildings are dedicated to data center use. Through their idealized design for this use, they are genuine ultra-high-performance digital factories that often house several data halls (IT rooms) opened as the building fills up, like the DC 03 type. These buildings are generally very large and sometimes built in urban expansion of former farmland, forest or natural spaces. This group contains several projects.

The location in the metropolis: mainly in less dense communes of the Paris conurbation and communes outside this conurbation.





Urban fabric
Not at all dense. Mostly ocated in economic activity zones or in immediate proximity. Often near highway infrastructures.

Insertion of the data center into its site
Most of the time occupies a building dedicated to this use on a plot that is much larger than the built portion's footprint. The land unit sometimes has other buildings with a similar shape and appearance (private campuses).

Installation process
In new construction, these data centers are often examples of the land artificialization of farmland, natural spaces and forests.

Size
Very heterogeneous, many of these data centers do not exceed 2,500 m2 of IT area, whereas certain of them are very large: 4,000 m2, 9,300 m2 even several with 10,000 m2 of IT area (the Cloud HQ project in Lisses projects 80,600 m2 of IT area divided among three buildings).

Construction period
The most recent type. Half of these data centers were built after 2020, the other half between 2000 and 2010. A single one was built before 2000.

Data center service start-up period
The service start-up of this type globally corresponds to the building's construction date.

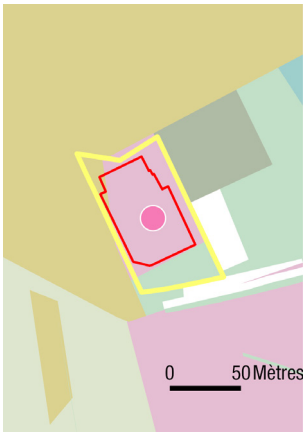
Building characteristics and landscape impact
Type of data center that most brings to mind the "digital factory" as often described in the media. These are large buildings (or multi-building sites) on the edge of urbanization. The façade's architecture has sometimes been carefully worked. The building is horizontal and no higher than two levels. The sites often included a planted part, but they are heavily secured (fences, surveillance cameras, security guards).

Evolution
Medium-level. Low reuse potential of this specialized building for another use, but large size of the land unit makes it possible to imagine other uses after the building is demolished. Recent data center with probably good reinvestment potential for use of another data center.

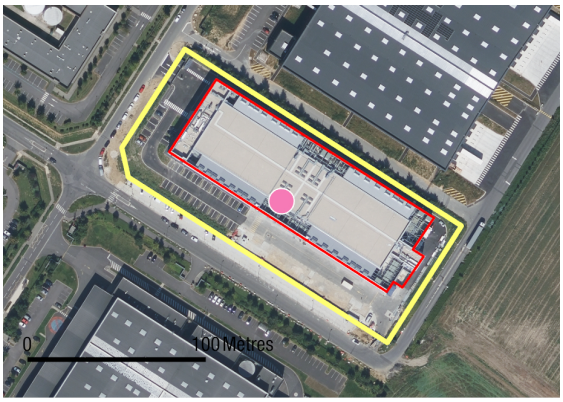
SITE A Thésée in Aubergenville (78)

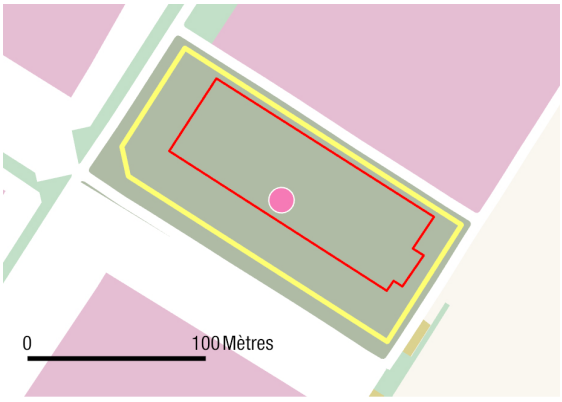
This recent data center (2021) is one of those that is the farthest from the center of the metropolis. In the end, Thésée plans for five other buildings. The first one built has an IT area of about 1,100 m2 divided between two rooms.

Source: L'Institut Paris Region, 2023



SITE B Digital Realty PAR12
in Ferrières-en-Brie (77)

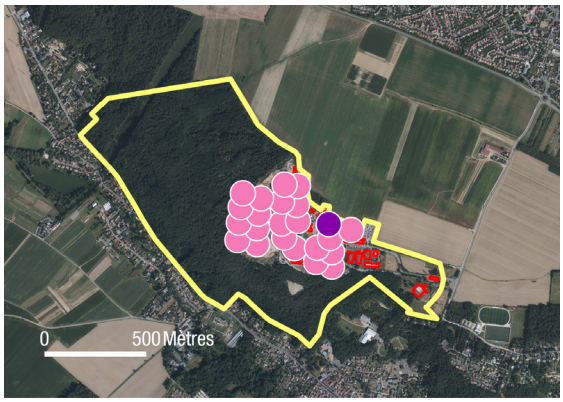


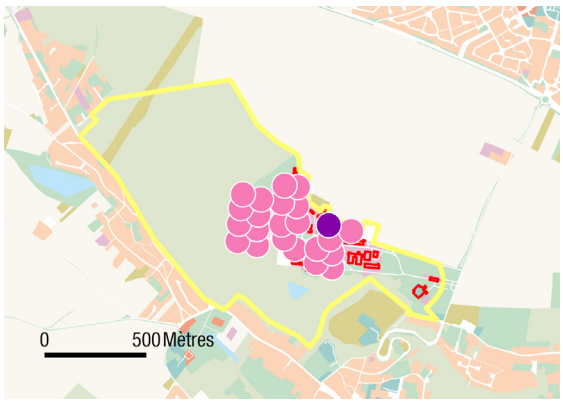


Built in 2021/2022, this Digital Realty data centre is located in the economic activity zone Bel Air, just off the A4 motorway. This former agricultural plot (MOS 2003) was awaiting commercialisation until 2020.

Source: L'Institut Paris Region, 2023

SITE C DATA4
in Marcoussis (91)





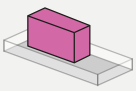
The DATA4 campus is undoubtedly one of the best-known data center sites in Île-de-France. 13 buildings were built between 2007 and 2020 (including one transformation) on this former Alcatel site. With large land reserves (notably in forests), the operator is planning the construction of 10 additional buildings.*
Source: L'Institut Paris Region, 2023

* In 2023, DATA4 announced another project nearby: a new campus on the former Nokia site in Nozay (does not appear on the map).

An increasingly frequent type of data center...

30 %
of data centers in the Paris region (51 out of 168)

Not at all dense sites…



18 %
land take coefficient on average (density of the plot)

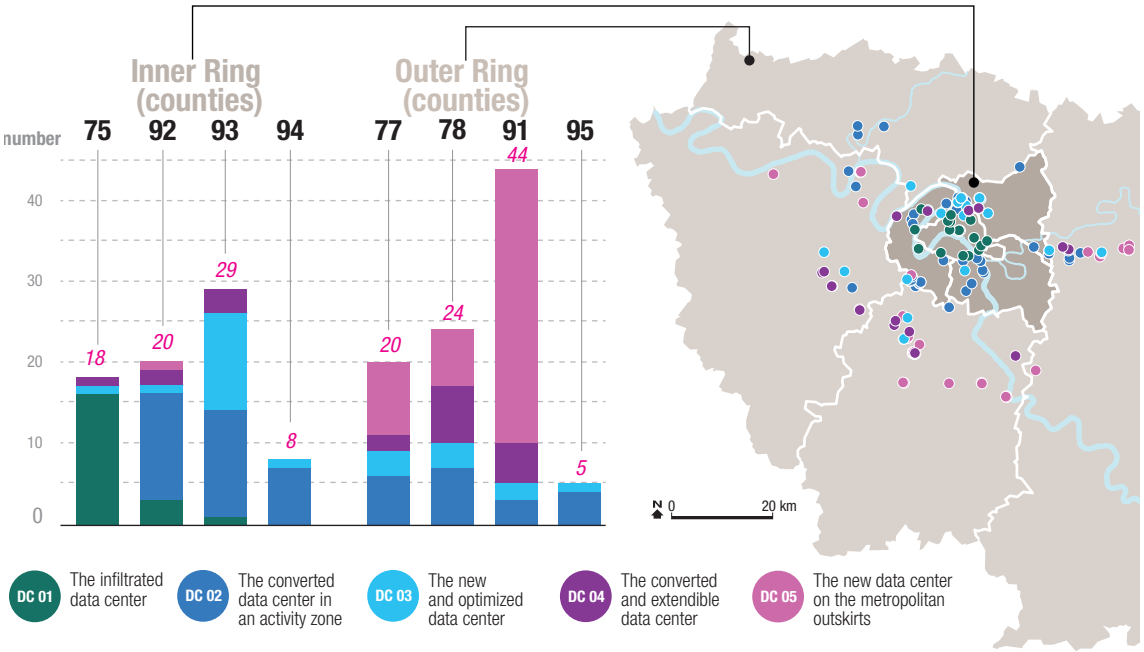
Buildings exclusively reserved for data center use

10 out of 10
buildings of this type reserved for data center user

2.3 OBSERVATIONS, SITING CRITERIA AND DEVELOPMENT TRENDS

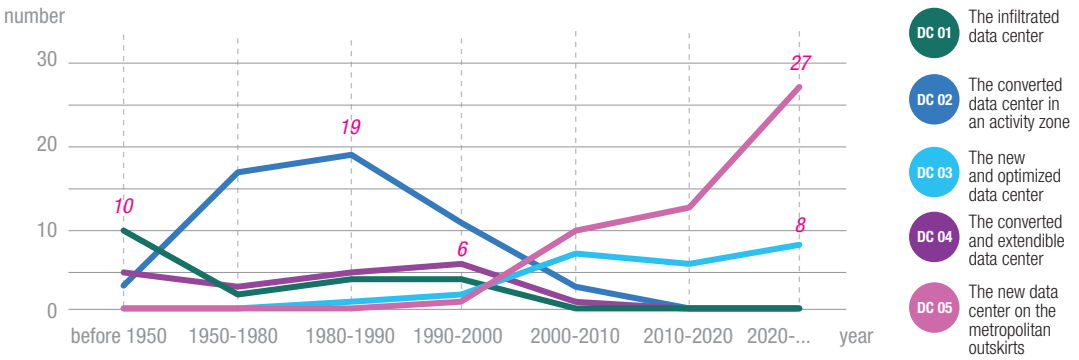
The analysis of data center types makes it possible to better understand their spatial organization in the region and to observe certain trends.
As for the DC 03 types – "the new and optimized data center, DC 04 – "the converted and extendible data center, DC 05 - "the new data center on the metropolitan outskirts," this almost exclusively concerns buildings dedicated to the use of data centers. Data centers of the DC 01 type – "the infiltrated data center," and to a lesser degree part of the buildings of the DC 02 type — "the converted data center in an activity zone," bring together most of the mixed-use buildings.
The area reserved for data centers has had a tendency to increase between the five types. Certain large data centers that are integrated into existing buildings are the exception. On the contrary, the building's age decreases between the DC 01 type and the DC 05 type. Recent projects for the most part are the DC 03 type – "the new and optimized data center" and DC 05 – "the new data center on the metropolitan outskirts" and more specifically in specialized buildings reserved for data center use and often in expansion.

BREAKDOWN OF DATA CENTERS IN THE DEPARTMENTS OF THE PARIS REGION



Number of *département* (county): 75 = Paris, 92 = Hauts-de-Seine, 93 = Seine-Saint-Denis, 94 = Val-de-Marne, 77 = Seine-et-Marne, 78 = Yvelines, 91 = Essonne, 95 = Val d'Oise

TYPES OF DATA CENTERS ACCORDING TO THE CONSTRUCTION PERIOD OF THEIR HOST BUILDINGS



Crossing this typology with the types of data centers (see chapter "Data centers, specific buildings and sites"), certain observations warrant being mentioned here:

- the colocation actors occupy large buildings dedicated to the use of data centers (specialized or transformed buildings);
- the international operators (Digital Realty, Equinix...) rarely occupy buildings of the DC 05 type – "the new data center on the metropolitan outskirts" or the DC 01 type – "the infiltrated data center";
- certain French data center actors (Data4 but also Thésée) and infrastructures specialized in one major customer (large companies, banks, laboratories, public actors) often concern the DC 05 type and occupy land that has been extended and/or enormous land units;
- a park's own renewal process can be observed (data center taken over by another operator).

As we have seen in this part, the matter concerns a sector that is evolving particularly rapidly due to technological progress, as well as evolutions in expectations on security, energy efficiency... An installation can already be technically obsolete after scarcely a decade. What future will the existing data centers therefore have? What will their transformation possibilities be? And for new data centers, what will the development dynamics be tomorrow?

Taking account of the **principal territorial siting criteria** of data centers for private actors (DC operators, real estate actors [CBRE]...) that are...

- an electricity availability and this within the shortest time (the criterion on access to decarbonated energy is making itself increasingly heard, guaranteed in France by the nuclear sector);
- land availability;
- a local political climate that is welcoming for digital companies;
- rapid administrative, regulatory and transactional processes;
- proximity to other data centers (only for certain operators);
- proximity to the internet backbones;
- access to water for the cooling systems;

... and the dynamics of the types of siting territories and insertion logics cited above, hypotheses can be made on the development of tomorrow's data centers that might occur without a supra-local or even regional strategy:

Development trends:
Growth should continue...

- where a favorable local political context exists (digital transformation approach, relaunch of the economic fabric by tech...);
- in project sectors (regional interest operations perimeters, economic activity zones...) and on plots available in new economic activity sites;
- where the urbanization potential has still not be reached;
- in aging business parks and/or abandoned buildings and wasteland;
- where the local urban planning document is not opposed to such an installation (according to the purpose);
- where there are no particular curbs in terms of electricity or internet network availability.

And it should slow down...

- where dense territories and those in urban transformation (ex.: Plaine Commune) are faced with increasingly great urban pressure and where there is a need to reduce pollution and/or urban dissection for the population at the same time as the improvement in living environment (by creating green spaces, public facilities, etc.);
- where there is reticence and/or local mobilization against land artificialization or in favor of an alternative project in a denser milieu;
- in sectors where there is local tension on the electricity transmission and distribution networks.

3 • ISSUES

3.1 A RESOLUTELY SPATIAL, REGIONAL AND TERRITORIAL APPROACH

The immediacy of the relationship to connected objects, in the same way as the lightness even the immateriality suggested by the vocabulary of the digital ("cloud," "virtual," "dematerialized," "wireless") suggests that the digital systems is neutral, transparent, that its development like its functioning do not have an impact on the environment, society, economy or space. However, mobile phone antennas, optical fiber networks, underwater cables or data centers are tangible realities that consume natural resources for their production and their use and, through the digital services that they provide together, modify life-styles and living and work environments. It therefore is a matter of better understanding the development and functioning of the digital system, and here more specifically, of data centers, to try to minimize their negative impacts and maximize their positive impacts.

An inspiring analysis framework: the global approach

In the 1980s, the digital's promises were mainly concerned with the environment: there was going to be a reduction in the consumption of raw materials, notably by shifting to "zero paper," and that of energy, by avoiding needless travel. But travel continued to increase (the ease of remote communication making the needs of physically meeting grow), in the same way as paper consumption (the ease of exchanging and handling documents making the number of printed documents increase) and now cardboard (explosion of online commerce augmenting the volume of packaging to be produced). From a sure solution, the digital then became a possible problem for the environment.

Starting in the 2000s, the pressure exerted by the digital system on resources and milieus became the subject of a gradual awareness-raising on the part of various actors, with diverse concerns: managers of IT departments of large groups concerned about improving their environmental reporting or simply reducing their energy bill, non-governmental organization worried about the consequences of the extraction of rare materials or the export of electronic waste to emerging countries, local residents and businesses exposed to cell tower waves or the noise of data centers... This awareness was structured during the 2000s, notably in France on the initiative of public and private network actors such as the Eco-Info group of the CNRS (French National Center for Scientific Research) and the GreenIT.fr galaxy, which applied to digital products and services the global approach proposed in 2002 by the international standard ISO14062 relative to the eco-design of products and services.

To evaluate the effect on the environment of a given service (ordering a train ticket, managing one's heating system...), the global approach considers both all the equipment mobilized (data center, stationary or mobile terminal, sensors...) to provide this service, but also the whole "life cycle" of each of these pieces of equipment (design, production, distribution, use, end of life...) and finally all the potential environmental impacts (climate change due to greenhouse gas emissions, exhaustion of fossil resources, overconsumption of water...).

In 2021, the iNum report published by GreenIT proposed a first synthesis, on the national scale, of the environmental impacts of the different components of the digital system.[46] This synthesis underlines the preponderant weight of the uses and especially the manufacturing of the terminals (grouped here in the same category "Users") and the relatively limited weight of data centers (called IT centers in the diagram below), except in terms of primary energy consumption in the use phase and in terms of mobilizing material resources in the manufacturing phase.

More recent publications, notably the ADEME-ARCEP study "Évaluation de l'impact environnemental du numérique en France"[47] published in several sections between 2022 and 2023, confirm the relative weights of the different environmental impacts, notably those of the manufacturing phase, which remains particularly strong whatever the scenario, more or less sober, retained in terms of the global development of digital services: "The manufacturing phase concentrates the majority of the impacts for the carbon footprint and abiotic natural resources (metals and minerals) (...) for (...) the data centers."[48]

%	ENERGY		GREENHOUSE GAS		WATER		RESOURCES	
	MANU	USE	MANU	USE	MANU	USE	MANU	USE
USERS	37%	27%	76%	8%	86%	5%	79%	0%
NETWORKS	2%	19%	5%	5%	1%	4%	15%	0%
DATA CENTERS	2%	13%	2%	4%	1%	3%	6%	0%
	41%	59%	83%	17%	88%	12%	100%	0%

6.2% OF CONSUMPTION IN FRANCE

3.2% OF EMISSIONS IN FRANCE

2.2% OF CONSUMPTION IN FRANCE

EXCAVATION OF **4 BILLION** TONS OF EARTH

46. Principal source for environmental impacts on the national level: https://www.greenit.fr/wp-content/uploads/2021/02/2021-01-iNum-etude-impacts-numerique-France-rapport-0.8.pdf

47. ADEME and ARCEP, "Évaluation de l'impact environnemental du numérique en France," 2022-2023.

48. ARCEP, "Note de synthèse [de l'étude Évaluation de l'impact environnemental du numérique en France] au gouvernement," March 2023.

Persistent limits

Like many other publications, the iNum report also suggests, indirectly, four persistent difficulties in evaluating the impacts of the digital system in general and data centers in particular, that it is important to have in mind when tackling the issues of the development of data centers in Île-de-France :

- A difficulty in comparing the impacts (more negative but not only) of the digital system and the impacts (more positive but not only) of the digital services provided, notably vis-à-vis the equivalent nondigital services: if we take the example of the online order of a train ticket (compared to its purchase at a train station), we can relatively easily estimate the quantity of primary energy, water and other resources consumed by the mobilized equipment (PC, wired network, data center...), but with ever more difficulty, the economic, social, environmental and urban impacts of the service provided (economic and environmental impact of travel in a station avoided, social and urban impact, notably in terms of activities and surveillance in venues receiving the public, disappearance of a ticket sale counter/terminal in a train station...);
- An absence of evaluation of the impacts of the digital system on the regional and territorial levels: the national estimate of impacts is completed, on the local level, by impact studies periodically conducted on the framework of the environmental evaluation of data centers projects,[49] which also take an interest in certain specific components of the environment (noise, heat, risks, biodiversity...). However, the national and the local levels, no evaluation has been made yet of the impacts on the regional and territorial levels, notably on the resilience of the electricity distribution networks, the integrity of large-scale landscapes, the functional specialization of spaces...
- An absence of consideration, beyond the environmental impacts "in the strict sense" (energy, water and material consumption, greenhouse gas emissions...) of the digital system, its urban, landscape and more generally spatial impacts (urban dissection, consumption and fragmentation of farmland...);
- Finally, a difficulty in taking into account certain specificities, previously mentioned (Part 1.1), of data centers within the digital system: strong "sensitivity to the load," growing virtuality and very great diversity.

These limits warrant being better shared so that collectively they can be overcome.

Clear options

This report does not claim to overcome all these difficulties, but intends to take a particular interest:

- **In the impacts of data centers on the regional and territorial scales** (and not only national and local),
- **In the urban, landscape and more generally spatial impacts of data centers** (and not only environmental "in the strict sense") of the development of data centers in Île-de-France.

Themes \ Scales	1. Worldwide and national	2. Regional	3. Territorial	4. Local (project)
consumption of space		*	*	*
urbanity			*	*
landscapes			*	*
biodiversity			*	*
technological risks				*
natural risks				*
pollution				*
waves				*
noise				*
heat island			*	*
GHG	*	*	*	*
energy	*	*	*	*
water	*	*	*	*
materials	*	*	*	*

The asterisks in the table indicate the components of the environment on which it seems relevant to take an interest in the impact of data centers. Initially, we only indicated a single asterisk in each spot, but 1 to 3 asterisks could also be indicated, according to relevance, by distinguishing by different colors what is usually evaluated today (in black) of what should be evaluated tomorrow (in red).

49. See MRAe d'Île-de-France "Éclairages 2022 : Les centres de stockage de données",2022.

However, the purpose of this report is not to question the rhythm of the development of data centers on the worldwide, or even the national or regional scale, that is the growth rhythm of the supply and demand of digital services. This limit in the report warrants being underlined:

- On one hand, because in a general context of the growing political assertion of sobriety issues (land sobriety, energy sobriety...) the idea of questioning the exponential growth of digital services now seems surprisingly little present in the public debate (see opposite the boxed text on digital sobriety); yet, can a climate policy, for example, be imagined that would settle for the adaptation element, without contributing "upstream" to the attenuation of the growth of greenhouse gas concentrations in the atmosphere?
- On the other hand, because digital services are likely to have themselves (independently of the digital system that makes them possible) spatial, and notably urban, very concrete impacts, without doubt at least as strong as those of the development of data centers: development of autonomous vehicles, multiplication of dark stores and dark kitchens (also called cloud kitchens), disappearance of neighborhood businesses, restaurants, movie theaters...

3.2 A MULTIPLICITY OF THEMATIC ISSUES

Some of the issues that follow are linked to the location of data centers (and therefore to the question of "where?") and for others connected to their other characteristics (and therefore more to the question "how?"). If the environmental authority is interested in an exhaustive manner in all these characteristics, going as far as taking into account, for example, "the life span of IT equipment, their life cycle from manufacturing to possible recycling...," we pay particular attention here to the characteristics likely to have positive or negative spatial (urban, landscape...) impacts.

We have taken an interest in these characteristics of data centers not only in their regular operational phase, but also in the construction phases (risks, potential pollution linked to the construction itself in the same way as the transport of building materials or demolition...) and dismantling at the end of life, but also during possible incidents even accidents. Among the issues linked to the location of data centers (type of territory, type of urban fabric, type of site...), that of the relative location of data centers in relationship

The digital sobriety issue

The term "digital sobriety" was introduced in France in 2008 by Frédéric Bordage, founder and leader pf the GreenIT (greenIT.fr) community and designates "the approach that consists in designing more sober digital services and moderating is daily digital uses."

A recent article in *the Revue de l'OFCE*[50] recalls the principal energy, environmental, health and social impacts of "digital pollution," by recalling that it is considered by a report by the Senate as "a blind spot of environmental and climate policies,"[51] but also identifies the principal curbs today on "digital sobriety" that alone would make it possible to reduce these impacts:

- "non-internalized negative externalities,,
- IT problems,
- a limited rationality on the part of users."

To remove these curbs, a report by the French association The Shift Project stresses the necessity of collectively defining a "built and thought-out use system": "The digital sobriety approach consists in shifting from a digital that has become instinctive to an aware and thought-out digital. It is necessary to identify the societal contributions of the digital to be preserved and developed, in order to be able to allocate as a priority the available resources. The question of the "usefulness" of a contribution is of course a subjective one, but that is necessary to collectively raise if we want to ensure the resilience of the digital system."[52]

A recent study by the ADEME and the ARCEP,[53] which envisages four prospective scenarios of the evolution of greenhouse gas emissions for the entire life cycle of the digital leading to very contrasting results (from -45% for the "Frugal Generation" scenario to +372% for the "Reparative Wager" scenario) concludes in the necessity of a genuine "societal choice."

50. Nicolaï Jean-Philippe, Peragin Lise, "Les certificats de sobriété numérique comme instrument de régulation de la pollution numérique" in Revue de l'OFCE, no. 176, 2022/1, pages 229 to 249.
51. Territorial development and sustainable development commission of the Senate," Rapport de la mission d'information sur l'empreinte environnementale du numérique," 2020.
52. The Shift Project, "Déployer la sobriété numérique," October 2020.
53. ADEME and ARCEP, "Évaluation de l'impact environnemental du numérique en France," 2022-2023.

ADVANTAGES

Clusterising

An ideal location in the region:
- Identifying a well-chosen site, far from the inhabitants for less pollution and fewer risks for the population;
- Limiting the urban sprawl effect and real estate development pressure;
- Limiting the activity eviction effect.

Possibilities for land, energy and resource sobriety:
- Rationalization of land use: fewer needs for space, thanks to an intensive use of the existing land (fewer volumes lost, pooling of parking areas, etc.);
- Efficient and responsible management of the land over time thanks to the existence of a cluster manager (on the model of activity park managers);
- Setting up a waste heat recovery system thought of on the right scale, in liaison with the surrounding neighborhoods;
- Requiring energy efficiency levels;
- Studying the possibility of coupling cluster to renewal energy production onsite or nearby; reducing water consumption (example: shared graywater loop); economy of scale: grouped orders of geo- and bio-sourced materials.

Anticipation and coordination: creation of electricity and internet networks
- Permits the network managers to better project themselves, avoid tension and rationalize the electricity structures to be built. The construction of an electricity infrastructure is costly and is a long process;
- Rationalization of the network: fewer marginal adaptations of the network to the grid, but a grouped investment for the electricity and internet networks.

Taking hold of the subject by the public actors:
- Proposing a thought-out spatial organization and urban programming, based on a complete analysis of the externalities;
- Shared knowledge and follow-up of the projects on the part of all the actors involved;
  Supervision through a limited number of urban planning documents (as in France PLU, SCoT, SDRIF) with possibility of incorporating programming, spatial organization, quality (architecture, materials, treatment of surroundings) and landscape preservation (continuities, view cones) conditions.

A better dialogue with the DC sector:
- Facilitating the approaches, more clarity on the administrative processes;
- Sharing the estimate of needs-targets;
- Facilitating the search for a location;
- Making the region attractive: access to equipped locations and more resilience;
- Possibility of bringing together needs (backup, technicians...) and bringing opportunities closer (customers, interconnection...).

Dissemination

An economic equality of the Paris region territories:
- Siting of digital actors according to land and market opportunities.

A flexible siting and programming adapted to each context:
- More ease in integrating individual operations in urban fabrics;
- Possibility of greater mixing with other functions;
- Possibility of reusing existing buildings by transforming them.

An electricity and internet network development that is more dynamic and closer to demands:
- Reduction of time frames to concretize projects (compared to the cluster), which depends nonetheless on the initial electricity situation and the size of the projects to be connected;
- Lower concentration of loads on the electricity network, which can however create a multiplication of local constraints and general saturation.

A breakdown of risks and pollution
- Breakdown and decrease in risks over the entire Paris region.

DRAWBACKS

Clustering

Relatively long development time of a cluster for:
- The choice of one or more sites on the scale of the region;
- The definition of project initiators;
- The sizing of each cluster;
- The consolidation of electricity infrastructures;
- The zoning in urban planning documents.

Reinforcement of territorial inequalities:
- The added value of certain sites chosen to the detriment of others.

A significant need in area for the creation of a single-function zone. A concentrated residual heat production, in stead of a distribution closer to users.

A new economic investment opportunity that will create a breath of fresh air: what data center strategy to be adopted on a cluster? Prioritization of a certain type of data center?

Dissemination

Considerable land needs everywhere in Île-de-France
- Weakening of the sites' intensification potential;
- Encourages development on large sites in urban expansion;
- Encourage the construction of large volumes.

Limited possibilities of public actors taking over the subject:
- Difficulty in following the projects and understanding the phenomenon and dynamics (opacity of the sector);
- Fewer chances to have a specialized region emerge (like the Amsterdam region specialized in hyperconnectivity).

to each other, that is "clustering" (see table opposite that sketches the first discussion elements on the choice of a clustering or dissemination strategy for data centers in Île-de-France) within the same territory, the same neighborhood even the same site, will warrant particular attention.

Issue 1: land sobriety and preservation of open land

Issue of reusing existing data center sites and abandoned sites/wasteland in the urban milieu, in consideration of the following trends:

- Tendency to site new data centers in urban expansion rather than in urban renewal, both due to the global growth of needs and the difficulty in mobilizing the sites in renewal (existing or dismantled data centers sites, urban wasteland from other uses...); this difficulty results on one hand from the quantitative (large-size data centers) and qualitative (security, accessibility) evolutions of data centers, and on the other from the growing necessity of favoring uses other than data centers for the reuse of urban wasteland (circular economy, renewable energies...);
- Tendency to abandon the oldest existing sites, notably in the center of the Paris conurbation but, at the same time, emerging demand for a "cloud of proximity" ("cloud at the edge" or "cloud in the field") likely to encourage the reuse of abandoned sites.

Issue of optimal use of data center sites, in expansion as in renewal.

We can globally note a very low land take of the buildings on data center sites in Île-de-France, including some of the most recent. However, densification (in m^2 of data center area per m^2 of land take and/or in m^2 of land take per m^2 of the plot's area) can strongly increase a site's demand for electrical power since we consider that the unit demand for power (per m^2 of the data center's area) is relatively stable over time.

Furthermore, densification (in m^2 of the data center's area per site) can occur to the detriment of the mixing of functions within the site concerned and of the preservation of open land.

That is why we speak here of optimal use, that is, reasoned use, rather than simply densification.[54]

Issue 2: urban integration

Issue of insertion into a mixed activity fabric

This insertion issue warrants however being strongly connected with the potentially contradictory issue of "clustering," which implies a functional specialization on the scale of certain territories or areas.

Issue of mixing even hybridization of uses on the scale of data center sites.

Issue of preserving and requalifying urban, peri-urban and rural landscapes, which notably implies:

- Taking advantage of the siting of data centers to requalify and upgrade deteriorated landscapes, and therefore renew the economic attractivity of certain centers that are abandoned today (corridors of very-high-voltage electrical lines, airport noise zones, very isolated sectors...);
- Limiting the land take of parking spaces (see also the question of parking standards in local urbanism plans).

Issue of limiting urban cuts (physical or psychological obstacles in the urban fabric), notably linked to the size but also the configuration of sites and on the level of security required.

Issue of a more acceptable insertion.

Even if it complies with the regulations, an installation can create conflicts with local residents and businesses, notably because of its ultra-secure black box appearance. This issue also implies making use of the "showcase effect" by working on the relationship of the site to the public space, volumetrics, programming, in order to better integrate into the urban fabric and improve local acceptability.

54. See MRAe d'Île-de-France "Éclairages 2022 : Les centres de stockage de données," 2022: this note notably cites the recommendation made by the MRAe to the local urbanism plan of Marcoussis to "justify the choice of permitting the expansion of the DATA IV site with a low density of constructions" (p. 15).
It also recalls that "Certain projects have already made the choice of density, such as the Equinix data center located in Argenteuil (95). Although it is a hyperscale, it is installed on a plot of 17,116 m² for electrical power of about 232 MW. It thus attests to the fact that the density objective can be reached." (p. 34).

Issue 3: prevention of risks and pollution

Issue of preventing soil, water and air pollution, including during the construction phase, which notably requires:

- Limiting the quantity of stored fuel oil, for example by reducing autonomy from 72 to 48 hours[55] or by using other energy sources or vectors (we can note for example that the MRAe d'Île-de-France regrets that "the projects have not chosen other forms of energy like gas that could also be used"[56]);
- Guaranteeing the regular monitoring of leaks of fuel oil or other fluids, such as insulating oils (dielectric oils or sulfur hexafluoride, SF6) used in electric transformers, likely to contaminate soil, water or air; it is now possible to use recycled or regenerated oils in industry to limit the impact linked to the production of these fluids but especially biodegradable plant oils, to also decrease the risks of contamination of the milieus in the event of leaks;
- Guaranteeing the regular monitoring (biodegradability, phosphorus content) of water discharged by the data centers using an adiabatic cooling system (periodic pulverization of water in the circuits, then discharge of this water into the public sewer network), likely to indicate the necessity of building a water treatment micro-station onsite;
- Ensuring that the earthworks carried out during a worksite do not alter the quality of water tables by the addition of rubble loaded with pollutants;
- Making sure to limit rainwater runoff, notably by limiting land artificialization and the infiltration of rainwater on the site;
- Limiting air pollution by reducing the duration and the optimization of the operation of regular functioning tests of the backup generators.

Issue of fire risk prevention (the fuel oil in the backup generators is inflammable above 55°C), notably by using feedback from accidents that have already occurred in France (Strasbourg, 2021 and Clichy, 2023) and worldwide, which notably requires verifying the effective availability of water in fire hydrants.

Issue of limiting noise from the data center during its operation, and including in the worksite phase. "The data center installations generate high levels of noise, sometimes leading to the emergence of higher regulation levels. This is regulated by the decree of January 1997 relative to the limitation of noise emitted into the environment by the ICPEs [Establishments Classified for Pnvironmental protection]."[57] This issue seems insufficiently taken into account in impact studies and however:
"In Paris, for example, in the Sentier district, a collective of local residents and businesses complained about the noise caused by the cooling system of the data center located nearby. Legal proceedings were initiated to have this activity, which seemed incompatible with nearby housing, stop."

Issue of limiting the urban heat island effect, both by limiting land artificialization and limiting heat loss of the data centers.

Issue of limiting greenhouse gas emissions, linked less to electricity consumption (largely decarbonated in France) than to the consumption of fuel oil during regular operational tests of generators (see above, issue of preventing soil, water and air pollution), and especially the use of fluorinated gases, principally the hydrofluorocarbons (HFC), that are used in the composition of refrigerants and generating a climate heating power as much as 14,000 times higher than that of CO2; favoring alternative solutions (free-cooling, low-temperature geothermal energy).

Issue 4: sustainable management of energy

The sustainable management of energy on worldwide, continental and national scales is often placed at the top of issues linked to the development of data centers, well ahead of issues concerning land sobriety and urban integration on regional, territorial and local scales focused on in this report. Even if the available estimates can be clearly improved,[61] the digital system appeared in 2020 to represent, in France and worldwide, on the order of 5 to 6% of the total consumption of primary energy, and data centers alone on the order to 15 to 20% of this digital system consumption, that is, around 1% of the total consumption of primary energy. Despite technological and organizational innovations permitting greater energy efficiency, the energy consumption of data centers has continued to grow over the last few years, as much in volume as in the share of the total consumption of primary energy, because the volumes of stored, computed and exchanged data have very heavily increased.[59]
The energy impacts of the digital in general and of

55. Provided that the electricity networks are sufficiently resilient in the geographic sectors concerned.
56. See MRAe d'Île-de-France" Éclairages 2022 : Les centres de stockage de données," 2022 , p. 27.
57. See MRAe d'Île-de-France "Éclairages 2022 : Les centres de stockage de données," 2022, p. 32.
58. Notably see Masanet Eric et al., "Recalibrating global data center energy-use estimates," in Science, vol. 367, February 2020.

data centers in particular on supra-national scales being the matter of a societal even civilizational choice (see boxed section on digital sobriety in Part 3.1), they are discussed here principally on the regional, territorial and even local levels.
Moreover, energy supply comprising the principal item of operating expenses of data centers,[60] it must be noted that several of the issues identified below (sobriety, efficiency, security...) are as much of particular interest to data center operators as of general interest which the public actors protect. This could suggest that public actors can leave it to private data centers to respond to all the issues of the sustainable management of energy. However, certain of these issues are exclusively a matter of general interest, and are indicated as such in what follows.

Issue of the resilience of the electricity system, which implies:

- Avoiding the development of data centers in geographic sectors where there is pressure on the electricity network, which also requires the improvement and sharing, by the network operators (RTE for transport and Enedis for distribution) of knowledge of these sectors under pressure; however, it is necessary to distinguish here:
  - the "sectors under pressure," on which the data center operators can choose to install themselves at the risk of supplanting other uses that also are heavy energy demanders (industry, urban services...), which comprises a general interest issue;
  - the "fragile sectors" of the electricity network, notably concerning flood risk, which are a bit better known by the public actors but which the data center operators themselves divert in order to secure their electricity supply.
- Controling through regulations electrical power over-reservations (or over-booking), likely to create new sectors of pressure on the electricity network and/or limit access to electricity for other uses, but also to make the cost of reinforcing the networks weigh on the local administration upstream of the new electricity substations and lines created that here too are an issue of general interest; these over-reservations are linked to two phenomena:
  - on one hand, "over-anticipation,"[61] a tendency of operators to over-anticipate the effective filling of their building or site. The effect of this over-anticipation could be lessened by asking the operators to present a rising load curve of their project until the target power is reached. This could be accompanied by clauses negotiated to restore non-mobilized power to the local administration after a certain time period[62];
  - on the other, the "double connection," a tendency of operators to solicit the two network managers (Enedis whose distribution network is more agile can rapidly respond to the connection request, and RTE to the network which the operator wishes to be connected in the end), independently of possible needs in redundancy intended to secure the electricity supply in the event of a problem on the electricity networks.
- Provided that approval is received from the energy regulation commission, encouraging network managers to officialize their use of the power differential (between the subscribed power and the power really used by the data center) for other uses;
- Encouraging the data center operators to contribute to the balance of the electricity system on the territorial and local scale by mobilizing their backup infrastructure equipment (generators and batteries), following the example of the Stockholm Flex system already implemented in the Swedish capital:
  - on one hand, by disconnecting from the network and by using their backup supply to ease the electricity supply-demand system in case of tension on electricity generation (provided that the backup systems are not polluting!)[63];

59. *Ibid.* According to this article, the worldwide energy consumption of data centers only increased by 6% whereas the number of computing instances increased by 550% between 2010 and 2018's Signifying an annual decrease in energy intensity of 20% thanks to technological innovations.
60. The current energy crisis further augmented the significance of this expense item – notably see the article in L'Usine Nouvelle of September 29, 2022 ("La crise énergétique met les opérateurs de datacenters sous pression.").
61. In aiming at a high target in terms of connection power when the demand for connections is made to the electricity network managers (RTE, Enedis), the data center operators make sure that they obtain an infrastructure enabling a gradual load increase. The threshold is sometimes largely overestimated and never reached. One of the effects of this practice is an oversizing of electricity infrastructures, more costly and heavy than those that would be necessary in reality. To this is added the connection blockage of other public or private customers to come, which is notably problematic in tension zones.
62. Enedis is currently holding a dialogue with its customers so that power over-reservation is returned to the public two years after the service start-up of the site, and after commercial negotiation with the customers. Naturally, the customer is informed about this step when its connection demand is made so that it can best adjust its connection power, to limit the time it takes to set up the connection equipment and the related costs taken in charge by the customer.

  - On the other, by using their batteries to produce and store electricity to complement the network.
- When an existing data center is dismantled, anticipating the reuse of its site and the electrical power thus freed up, by uses that require a great deal of electricity (industry, urban services...) rather than by uses that require little (recent examples of data centers replaced by housing operations), especially when the siting of this data center required a reinforcement of the networks upstream whose cost was incurred by the public:

Issue of sobriety and energy efficiency making it possible to limit energy consumption, which notably requires:
- Encouraging more sober organizational design, notably by requestioning needs, following the example of Pôle Emploi,[64] which hosts its own data and is therefore directly interested financially in return on investment of the improvements undertaken:
  - decrease of air-conditioning needs by raising the maximum temperature of the technical spaces from 26 to 28°C;
  - optimization of the cooling system by the separation of cool and warm air flows with confinements in cool and warm aisles;
  - modularity of the technical installations in order to adapt the power called on by the IT demand.
- Encouraging the more energy-efficient mobilization of equipment (IT equipment and infrastructure); this concerns not only improving the energy efficiency indicator (power usage effectiveness or PUE) of the infrastructure (ratio of the total energy consumption of the data center and the energy consumption of the IT equipment), but also to improving the energy efficiency of the IT equipment itself;
- Making the regular tests of the generators more sober and limiting the noise and air pollution generated by these tests;
- Favoing a location in a sector that is well-served by public transportation, which here comprises a public interest issue.

Issue of mobilizing renewable energies and recovering energy, which notably implies:
- Privileging a location in a sector favorable to the development of renewable energies (solar, wind, geothermal... potential) and recovery (actual or future presence of potential recovered heat users, in view of connecting to existing heating networks or the creation of local loops[65]);
- Anticipating the installation on the site of renewal energy production systems (solar panels...);
- Anticipating the installation on the site of a waste heat recovery system, a practice that is likely to evolve that article 28 of the "Reen" law ("reducing the environmental footprint of the digital") of November 15, 2021 stipulates (but whose implementing decrees on the targeted PUE are still pending):
  - as a condition for benefiting from the reduced rate of the domestic tax on final electricity consumption, that "the digital data storage center recycles waste heat, notably through a heating or cooling network, or respects a quantified indicator determined by decree on a multiannual horizon concerning efficiency in power use.[66]
  - That the action programs defined by the territorial climate, air and energy plans notably focus on "promoting the potential in recovered energy, including the potential of heat recovery from data centers" and "reducing the environmental footprint of the digital."[67]

Issue 5: sustainable management of other resources

Issue of resilience of the water supply system, which requires avoiding the development of data centers in sectors where there is pressure on the water resource.

Issue of limiting water consumption by data centers, which requires finding a good balance between the use of energy (PUE, power usage effectiveness indicator) and WUE (water usage effectiveness indicator) and that is based on new solutions such as the use of graywater (Google in Douglas County in the United States).

63. The conversion of generators to biofuels has begun for the sector.
64. See feedback in Cigref, "Sobriété numérique : Piloter l'empreinte environnementale du numérique par la mesure," December 2021, p. 24..
65. We can cite here, as a reminder, the first examples of waste heat recovery in Île-de-France:
    - The most recent Equinix building, developed in a plot densification in Saint-Denis (93), and that will heat the future Olympic swimming pool in Plaine Saulnier from 2024,
    - A data center in Bailly-Romainvilliers (77), which also heats a swimming stadium,
    - The Ville de Paris/AP-HP data center in Chapelle Internationale (Paris 18th arrond.), which injects heat into a local loop,
    - The Interxion data center in La Courneuve (93) in the former Eurocopter factory, which has committed to delivering heat to the network operated by the SMIREC.

Issue of reducing the use of materials during the construction of data centers and facilitating their total or partial future dismantling, which requires an eco-design effort from data centers. This principally concerns limiting the consumption of concrete made with natural aggregates and steel that weighs in the data centers' carbon footprints. It also concerns designing data centers in such a way as to guarantee their mutability and future conversion. Finally, the use of materials. That come from the circular economy (from reuse, recycling...) must be encouraged notably for finishing work elements of the data centers.

This sobriety effort in construction materials and the evolution of the data center building should be accompanied by a similar effort for the IT equipment (servers...) and the infrastructure equipment (security, cooling and ventilation systems, generators), for which any renewal project must be the subject of a global evaluation based on the analysis of the life cycle, which alone makes it possible to compare the gains in efficiency enabled by the new equipment, with the environmental impact of their manufacturing and the dismantling of the old equipment.

66. Modification of article 266 of the Customs Code, which we can note in passing that it provides a legal definition of a data center: "A digital data storage center meaning a building infrastructure dedicated to the physical storage, processing, transport and dissemination of digital data whose access is secured, and including specific and dedicated systems to control its thermal environment, its air quality, energy supply and fire prevention..
67. Modification of article L229-26 of the Environment Code.

4 • PROPOSALS

An indispensable link in the digital infrastructure, data centers play an important role in the territories insofar as the problems that the digital raises on the planet. The financial resources of the data center actors and their appetite for innovation can become a lever for designing flagship projects in terms of sobriety and energy efficiency and in water and materials, but also concerning architectural quality and urban and landscape integration. The data center sector is continuously evolving, but the technological innovations and advances are more focused on the inside of the building than on its envelope and surroundings. Today, sites and buildings often remain functional, opaque and do not respect the environment. Enormous efforts can be made on the architecture and on urban and landscape integration, as well as on energy performance.

The proposals brought together here aim at accompanying the development of data centers in Île-de-France, by making sure to maximize their positive feedback and minimize their negative impacts. This concerns new installations and the existing data centers in which many improvements in landscape and urban integration and architectural quality can still be made later on.

The aim of these proposals is first of all for them to be discussed with the public and parapublic actors identified to comprise the first core of the "collective of public and parapublic data center actors in Île-de-France," which is proposed in this part of the work.

As of this day, data centers in the Paris region often break with the urban environment.
Source : L'Institut Paris Region, 2023.

4.1 DRAWING UP A REGIONAL DEVELOPMENT STRATEGY FOR DATA CENTERS

To better organize data center development in Île-de-France, the drawing up of a regional strategy that considers the major environmental, urban and economic issues of general interest seems indispensable to us.
This regional strategy should notably answer the following questions:

- **"What":** what are the types of data centers whose development should be favored? (See the many differentiation criteria presented on pages 15 and 16 of this report: according to the size, core/edge/hyperscale function, catchment area, level of electricity security, level of IT security, degree of sovereignty...)
- **"How much?":** for each type of data center whose development should be favored, what is the quantity desired (quantity expressed in floor area, number of rack units or electrical power)? What is desirable and possible to set the limits of constructability for the sector on the regional scale?
- **"Where?":** is it desirable and possible to orient the siting of data centers toward certain specific geographic sectors within the region ("clusters" of current data centers, other sectors...)?
- **"How?":** is it desirable and possible to encourage/force the data center siting projects in Île-de-France to respect certain concrete siting modalities (siting process to favor, energy savings, heat recovery, landscape integration...) that are complementary to those imposed by international or European standards, the national legislation, urban planning documents (as in France Sdrif, SCoT...)? If so, in what framework could these modalities be expressed (regional planning, "reference sheet on the orientations for the examination of approval applications for data centers," regional label or certification...)?
- **"Who?":** who are the existing actors that should be better associated with the drawing up and/or implementation of such a strategy? Who are the actors that do not exist yet but that should emerge, for example, to act as a trusted third party between the data center operators and the heating network operators?

This strategy can be based on preparatory work:

- **A strategic study identifying the most relevant siting zones** (in clusters or disseminated) in terms of electricity and land availability, heat recovery possibilities (distribution network) and the presence of other appropriate urban infrastructures (internet backbones, transportation, renewal energy sources, water...) and of course other uses that can be envisaged in the zones concerned. This study could also analyze the relevance of the creation of data center clusters and "envelopes" whose area and maximum electrical power are capped on the regional scale.

We present below the first reflection tracks for this study, whose specifications remain to be collectively discussed.

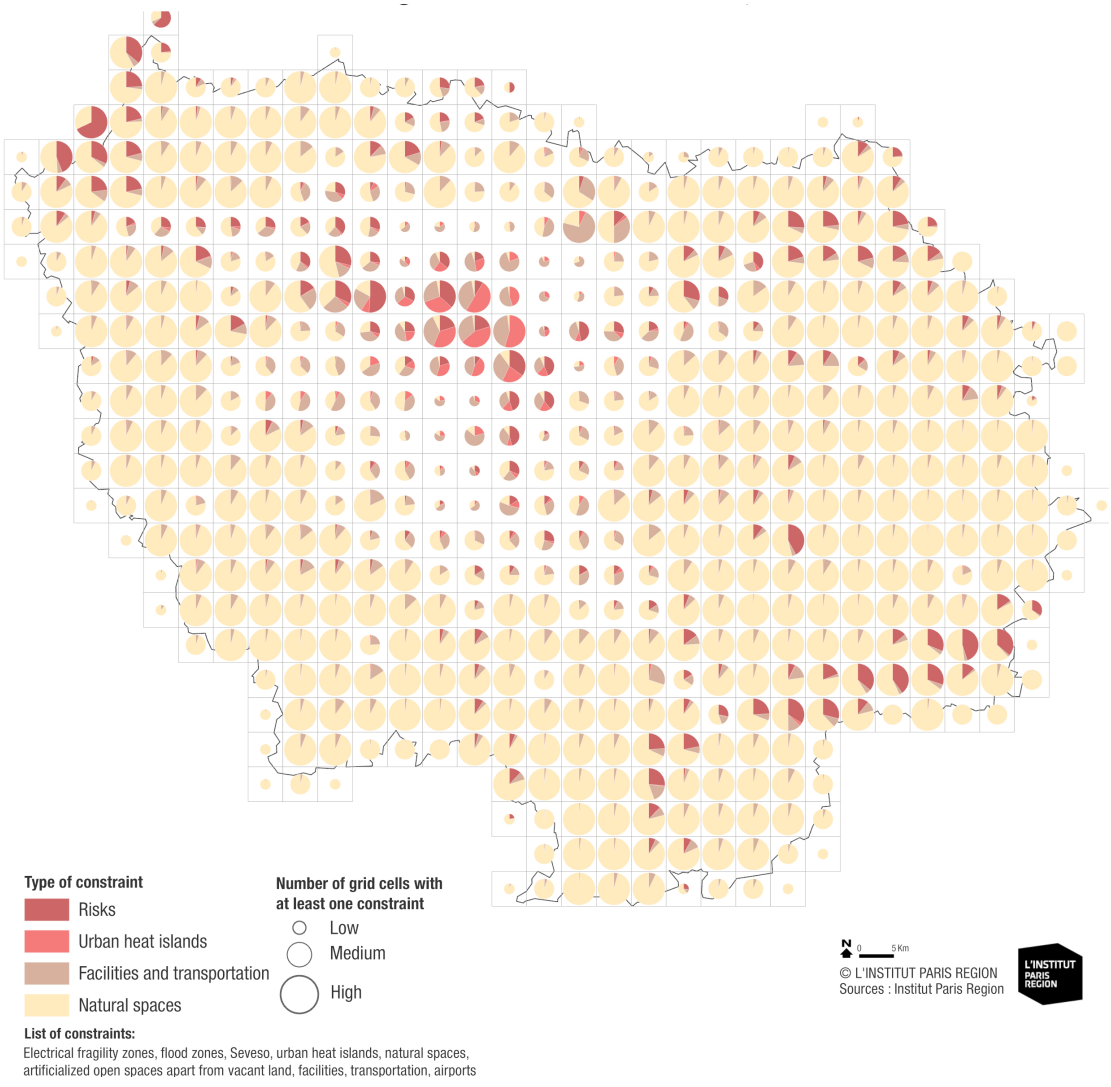
The purpose of the map below is to show the zones of constraints for the installation of data centers that are of at least 2 000 m² of floor area.
The construction of the map is based on the crossing of grid cells – 125 m x 125 m squares – and identified constraints.
The results are expressed in 5 km x 5 km square grid cells.
The colors of the disk sectors represent the share of each family of constraints:

- risks (electrical fragility zones linked to flooding risk, flood zones, Seveso-III Directive Sites);
- urban heat island effect (strong and medium);
- facilities and transportation: artificialized open spaces except vacant land (category 5 of 11 categories in the land use inventory of Ile-de-France), facilities (category 9), transportation (category 10), airports and natural spaces, farmland and forests (categories1,2,3 and 4).

The size of the disks represents the number of grid cells – 125 m x 125 m squares – that have at least one constraint within the 5 km x 5 km square grid cell concerned.
In the continuity of the map below, which exclusively shows the constraints identified for the siting of data centers, the map opposite proposes to also include the opportunities. Its purpose is to propose more favorable zones, and more specifically preferential sites, for the siting of data centers of at least 2 000 m² of floor area.
The construction method of this second map is similar to that of the first map.
The constraints considered are the following:

- risks (electrical fragility zones linking to flooding risk, flood zones, Seveso-III Directive Sites);
- urban heat island effect (strong and medium);
- facilities and transportations: artificialized open spaces except vacant land (category 5 of 11

ZONES OF CONSTRAINTS FOR THE SITING OF DATA CENTERS OF AT LEAST 2,000 M² IN FLOOR AREA



categories in the land use inventory), facilities (category 9), transportation (category 10), airports and natural spaces, farmland and forests (categories 1,2,3 and 4);
- economic activity zones to be preserved.

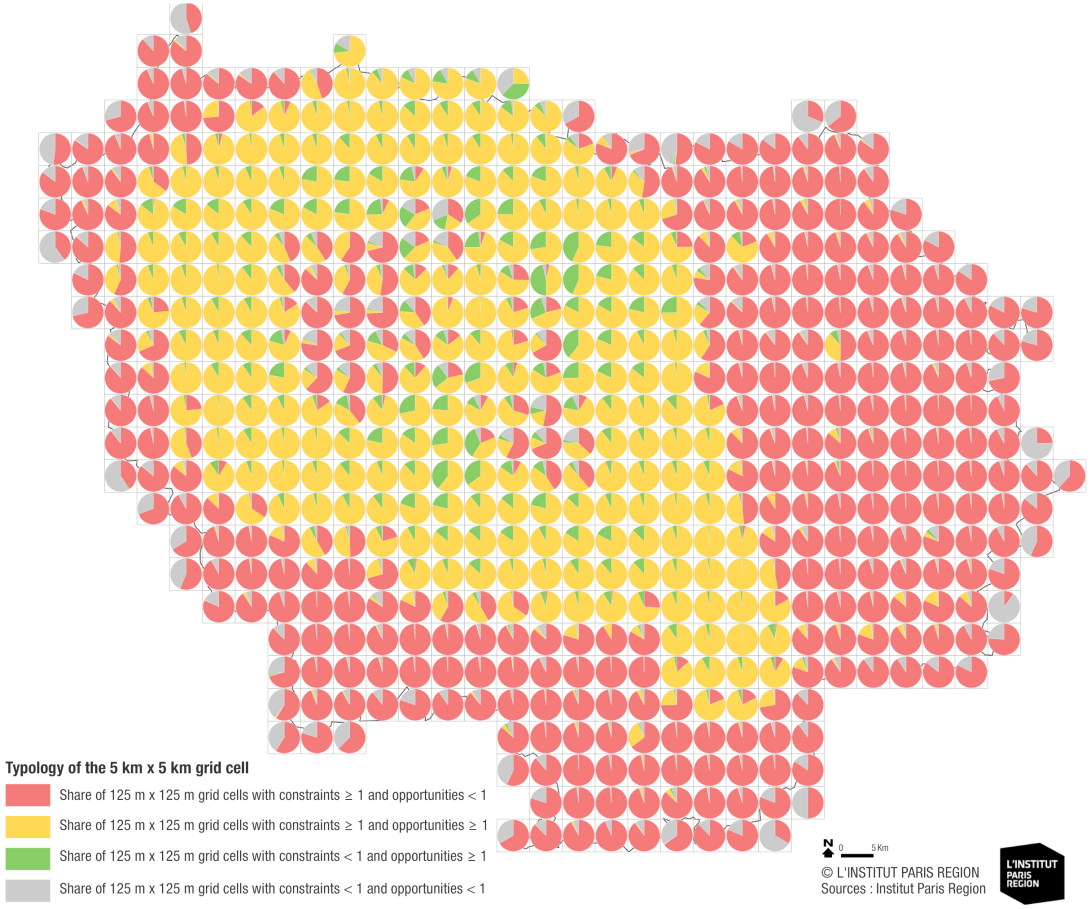
The opportunities:
- zones located less than a kilometer from an urban heating network;
- urban wasteland;
- economic activities in the outside dedicated business sector;
- economic activity zone outside zones to be preserved;
- ICPE (Installation Classified for the Protection of the Environment);
- proximity zone of an existing data center;
- land unit of an existing data centers
- zones located at least 10 kilometers from the Paris region structuring electricity ring.

The input data used to build this map globally correspond to the criteria mentioned in Part 4.2.

The results are expressed in the 5 km x 5 km grid cell. The colors of the disks represent the shares of the following four types, resulting from the crossing of the 125 m x 125 m grid cells with the constraints on one hand and the opportunities on the other:
- 125 m x 125 m grid cells with constraints and without opportunities, in red;
- 125 m x 125 m grid cells with constraints and opportunities, in yellow;
- 125 m x 125 m grid cells without constraints and with opportunities, in green;
- 125 m x 125 m grid cells with constraints and without opportunities, in gray.

These two maps should make it possible to contribute the visibility increasingly demanded by the public, parapublic and private actors, (local administrations, but also network managers and data center operators...) and, very concretely, to comprise a shared support for the government's approval policy for future data center projects.

MAP OF THE PRIORITY GEOGRAPHY FOR SITING DATA CENTERS IN ÎLE-DE-FRANCE

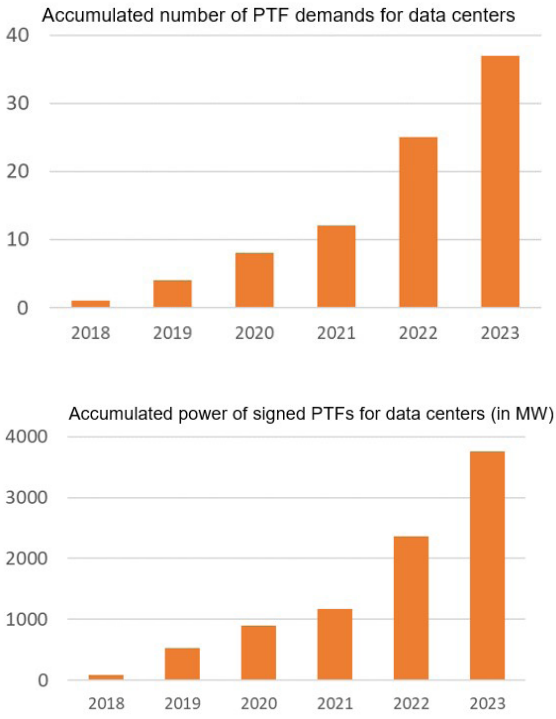


- **A regional electricity planning study** for 2025-2030, based on the shared estimate of global needs (in digital services, but also in electrical mobility...) defining scenarios with spatialized plans for the electricity and digital infrastructures on different scales and making it possible to have better visibility on the land needs of the network managers, in order to rationalize the occupation of the territory and minimize the creation of new infrastructures and therefore the cost for the local administration. The french transmission system operator RTE has observed today a strong connection dynamic in Île-de-France (in studies and signed contracts), initiated by the data centers. Internal research conducted by RTE in 2022 shows that this growth requires evolutions and reinforcements of the electricity network, with possible deoptimization effects without a consolidated vision. Constraints linked to power injection, transit and land can notably manifest themselves, generating increasingly complex and costly connections. Consequently, RTE recommends a positioning of large data centers and other heavy electricity consumers relatively near the 400 kV belt rather than in a dense milieu. An analysis of the large electricity pockets on the RTE network shows however a situation close to saturation for three (Villejust-Cirolliers, Plessis-Sausset, Morbras) out of 10 pockets. Less constrained, the other pockets have available capacities for the future development of data centers.

- **In-depth work on knowledge of the land and buildings available** in sectors favorable for siting data centers, in close collaboration with the EPCIs (public programs of inter-municipal cooperation) and/or the communes.[68]

L'Institut Paris Region can contribute to this work by notably mobilizing the database of wasteland in the Paris region that it has constituted over several years, in collaboration with the Région Île-de-France. Wasteland is often perceived as an urbanization reservoir but considering its characteristics, location, context and dynamics in which it is integrated, it can also be preferable to favor urban renewal operations (housing, industry, data center, offices...) or, on the contrary, undoing land artificialization and renaturing this wasteland to respond to environmental issues (shortage of green spaces, floods, urban heat islands...), preserve wasteland that is rewilded and now comprises biodiversity reservoirs, or rehabilitate farmland. The database can also be used to evaluate the mobilization potential of certain wasteland zones for the siting of data centers.

DYNAMIC OF DEMANDS AND CONNECTION TO THE TRANSMISSION GRID (RTE)



PTF: Technical and financial proposal (commercial offering)

68. As was done by the Amsterdam Metropolis for the drawing up of its strategy: cf. "Eindrapport MRA-brede strategie datacenters" (final report of the strategy of the MRA on data centers), in Dutch, Metropoolregio Amsterdam, CE Delft and Buck Consultants International, January 2020.

Data center « Marilyn » de Céleste, located in the Cité Descartes in Champs-sur-Marne. Source : L'Institut Paris Region, 2021.

4.2 TOWARD A SHARED PROJECT ANALYSIS GRID AND A JOINT STRATEGY

We are proposing here a first contribution to the drawing up of a shared analysis grid of data center projects between the public and parapublic actors in Île-de-France that can guide a regional siting strategy for data centers. It successively presents 11 detailed criteria and about 20 sub-criteria and can be grouped and organized according to the five thematic issues identified above (see 3.2 "A multiplicity of thematic issues") – see the table on the following page.

Most of the detailed criteria are divided into two types of sub-criteria:

- **a first sub-criteria related to the question "where?",** indicating if the project responds by its location to the issue considered (for example, "Through its location, does the data center project contribute to limiting the urban heat island effect?"; each "where?" sub-criteria is accompanied by a first sketch of a regional map making it possible to evaluate the projects in terms of the sub-criteria (for example, "Map of the sectors in which the nocturnal heat island effect is low or moderate"); this regional map presents, as a guide, the data centers already existing in Île-de-France listed in the Data Center Database;
- **a second sub-criteria concerning the "how?"** question, indicating if the project responds, through its concrete siting modalities (technical specifications, volumetrics...), to the issue considered (for example, "Through the presentation of its concrete siting modalities (cooling system, heat recovery), does the data center project provide credible proof that it contributes to limiting the urban heat island effect?"); each "how?" sub-criteria is accompanied here by the succinct presentation of a "good practice" example, notably taken from the Data Center Database in Île-de-France created by L'Institut Paris Region.

It will therefore be possible, based on the analysis grid, to allocate to each siting project a score of 0, ½ or 1 point for each of the sub-criteria and consequently to the total, a total score.

Taking into account the expertise of L'Institut Paris Region in regional development and urbanism, the criteria of urban and landscape integration and architectural quality are detailed more than the others.

We present the details of the 11 criteria and the 20 or so sub-criteria of the sketch of the shared analysis grid of data center projects, grouped and organized, as in the table below, according to the five thematic issues identified in Part 3.2 "A multiplicity of thematic issues."

Issue (see Part. 3.2.)	**Criterion**	**Sub-criteria**		
		"Where?" sub-criterion		"How?" sub-criterion
		The data center project is sited...	Reference map	**The data center project provides credible proof, in the presentation of its concrete siting modalities, that it...**
Regional development	1. Regional positioning (in the domestic and European markets)	*"Where?" sub-criterion not relevant*	-	... principally meets a regional need ("sovereign cloud"...)
	2. Priority regional geography	... in a sector of the priority regional geography	" Priority geography for the siting of data centers in Île-de-France " map	*"How" sub-criterion not relevant*
Local development: land sobriety (Issue 1)	3. Land sobriety	... in an existing data center site or on wasteland not appearing particularly relevant for other uses (industry, green spaces, biodiversity...)	"Densification potential in the land units of data centers" map	... presents an optimal density on the scale of the building and the land unit
Local development: urban integration (Issue 2)	4. Mix of functions	... in a mixed activity fabric	"Activity fabrics and data centers" map	... hosts mixed or hybrid uses on the scale of its site
	5. Architectural quality and landscape integration	... in a constrained urban environment (VHV line corridors, airport noise zones...) that it contributes to requalifying	"Constrained urban environment and data centers" map	... contributes to requalifying and/or preserving the urban environment
Risks, pollution (Issue 3)	6. Resorption and prevention of pollution	... on polluted soil that it helps depollute	"Polluted sites and soil" map	... limits the risks of soil, water and air pollution
	7. Resorption and prevention of the urban heat island effect	... in a low urban heat island effect sector	"Urban heat islands and data centers" map	... does not contribute to the urban heat island effect
Energy (Issue 4)	8. Resilience of the regional electricity system	... in a sector not presenting pressure on the electricity network, nor any particular adaptation complexity of the network	"Adaptation complexity of the electricity network" map	... limits the over-reservation of electrical power
	9. Energy sobriety and efficiency	*"Where?" sub-criterion not relevant (except to consider the distance by road or public transportation service)*	-	... limits its energy consumption (electricity, fuel oil...)
	10. Use of renewal energies and recovery	... in a sector favorable to the development of renewal energies and recovery	"Urban heating network and data centers" map	... includes the renewable energy production (solar panels...) or waste heat recovery systems
Water and materials (Issue 5)	11. Sobriety in water and materials	... in a sector that does not have medium or strong quantitative pressure on the water resource	"Pressure on the water resource" map	... limits its water and materials consumption and organizes the recovery and reuse of graywater and used materials

Regional development

Criterion 1 : regional positioning (in the domestic and European market)

The data center project provides credible proof, in the presentation of its concrete installation modalities, that it principally meets a regional need, that is, that it hosts the data of public or private actors in the Paris region (local administrations, companies) and notably responds to the issues of having a "sovereign cloud" (cloud environment that is limited to the territory of a country and that therefore makes it possible to respect the laws in effect in the country).

Criterion 2: priority regional geography

Insofar as is possible, the data center project is sited in a sector of the priority regional geography ("cluster," target zone"...) and notably in an ecosystem of digital actors in the Paris region. This also makes it possible to avoid tension on the electricity network to limit real estate development pressure and the phenomenon of evicting economic activities and pursuing the ZAN objective. Consequently the data center project is consistent with the regional orientations, notably

- in zones identified as priority, notably in existing data center clusters that are near the 400kv ring of RTE and capacity substations;
- outside exclusion zones (see list of "constraints taken into account, page 62).

This priority geography identifies sectors presenting attractive conditions and that permit a controlled and optimized development: good connection via fiber, electricity availability and land prepared with appropriate urban planning tools. A commercial model making it possible to buy the waste heat of the data center for urban heating is also created.

EXAMPLE
Criterion 1

Euclyde Datacenters DC6 – IDF in Lognes in Seine-et-Marne

The first sovereign data center in Île-de-France

Source : L'Institut Paris Region, 2022.

In 2019,the Euclyde group transformed this former HSBC data center into its 6th data center in France. Servers of private and public actors are hosted on this site on three stories, including one reserved for the sovereign data center part.

It is the Val-d'Oise department that had launched the initiative of a sovereign data center, first planned on its territory. On this occasion, an economic interest group for public community IT outsourcing (GIPC) was founded. Quickly joined by other public actors and universities, the decision was made to finally install it in Lognes. The Région Île-de-France installed its servers in this data center in 2020.

Each actor has, for itself, one or more separate compartments (pods) in which the racks are organized. Cool air is diffused solely by the floor in the pods and warm air discharged by the servers in the rooms, which means that the ambient temperature in them is relatively high. Between 2022 and 2023, work was carried out to reuse the waste heat of the building for the offices.

With a growing demand from many public actors to outsource the data in a secure and sovereign location, the GIPC is studying the possibility of opening a new Paris region data center.

EXAMPLES

As of this day, no priority regional geography has been defined in Île-de-France and that is why we cite European references here.

Definition of a priority location in Amsterdam and Stockholm[72]

The Schiphol-Rijk sector in the municipality of Haarlemmermeer has a large number of data centers, like this Digital Realty (Interxion) one.

In Hollands Kroon, north of the province of North Holland, hyperscale data centers are installed, like this Google one. Several other Microsoft data centers are located nearby.
Source : L'Institut Paris Region, 2020.

During the last few years, the galloping growth of data centers in the Amsterdam metropolis has created new tension situations, which are notably expressed spatially (little available land, high prices) and in terms of energy (saturated electricity infrastructures in certain zones). It is for these reasons that the municipalities of Amsterdam and Haarlemmermeer decided in 2019 to institute a moratorium on new data center constructions for one year. Since then, Amsterdam has adopted a framework document on data centers and Haarlemmermeer a framework document and a zoning plan.

On a higher scale, the province of North Holland drew up a data center strategy to regulate the locations of data centers. The policy of the City of Haarlemmermeer[70] will authorize limited growth (cap on area and electricity capacity) until 2030.

After 2030, no additional space will be used for data centers. In any event, data centers are authorized exclusively in certain economic activity zones and must fulfill conditions on landscape integration, energy consumption and sustainability.

The framework document of the City of Amsterdam[71] also defines a cap on electricity capacity, but is less restrictive on zoning. The document underlines the prioritization of location in already existing clusters and encourages the intensification of the plots invested by a tall construction. New sustainable rules must also be followed.

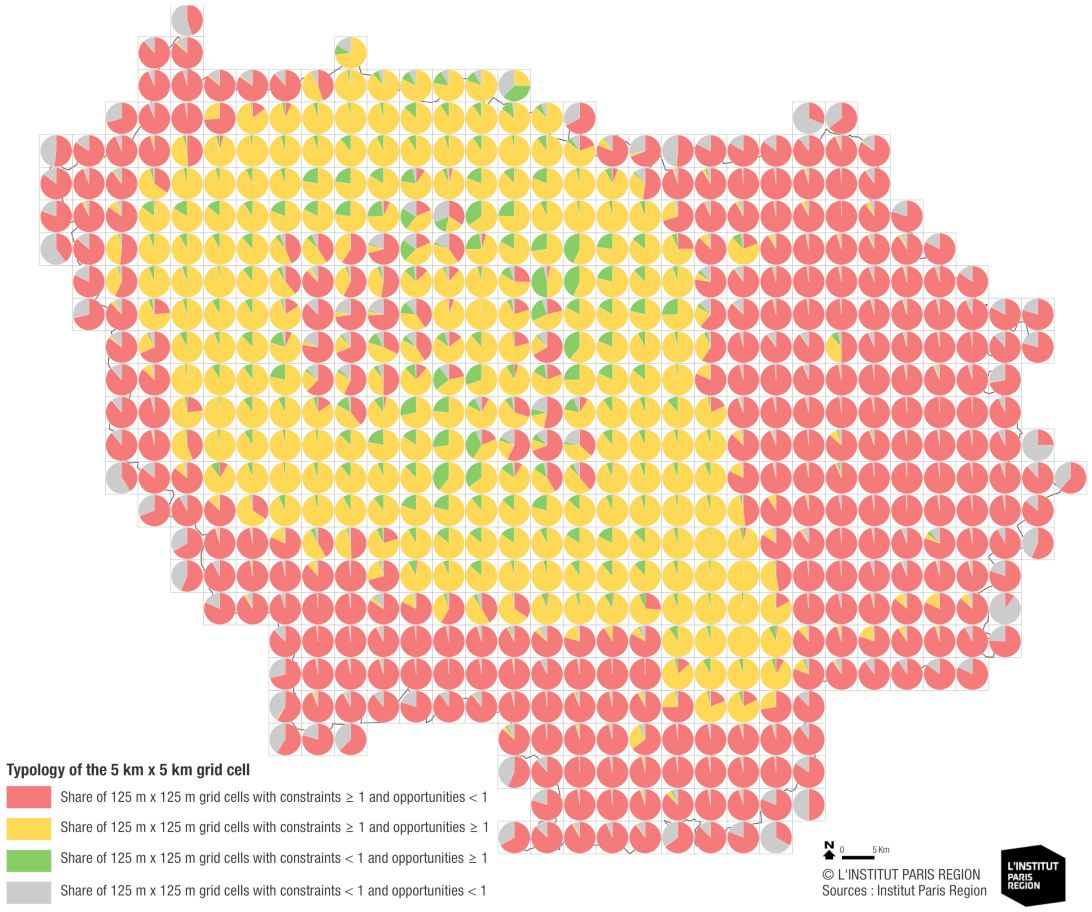
On a higher scale, the prioritization of certain zones is equally required in the strategy of the province of North Holland[72] that authorizes the development in four communes (Amsterdam, Haarlemmermeer, Diemen and Hollands Kroon) and here more specifically in chosen activity zones. The strategy excludes new constructions outside these zones and communes.

In the plans and strategies of North Holland and Amsterdam, these rules are not solely applied for data centers that exceed the capacities of 5 MVA. For Haarlemmermeer, the rules apply to all sizes of data centers.

Another priority location strategy concerns the Data Parks in Stockholm in Sweden.[73] This initiative has made it possible to control the expansion of colocation data centers in the metropolis, by offering them attractive conditions in three dedicated parks of several hundred hectares: renewable energy, connection to fiber, rapid and accompanied authorizations, free use of the city's cooling network... In exchange, the data centers contribute to the city's local energy system through heat recovery equipment that was made available to them.

69. Lopez Fanny, Gawlik Maximilian (codir.) « Data centers : anticiper et planifier le stockage numérique », Note rapide, n° 893, L'Institut Paris Region, mai 2021.
70. https://lokaleregelgeving.overheid.nl/CVDR646404
71. https://amsterdam.raadsinformatie.nl/document/10115471/1/Raadsbesluit_375_1544A_3a_20_bijl1%20Vestigingsbeleid%20datacenters%20gemeente%20Amsterdam
72. https://www.noord-holland.nl/Onderwerpen/Economie_Werk/Projecten/Datacenters/Datacenterstrategie
73. https://www.institutparisregion.fr/nos-travaux/publications/data-centers-anticiper-et-planifier-le-stockage-numerique/

PRIORITY GEOGRAPHY MAP FOR THE SITING OF DATA CENTERS IN ÎLE-DE-FRANCE



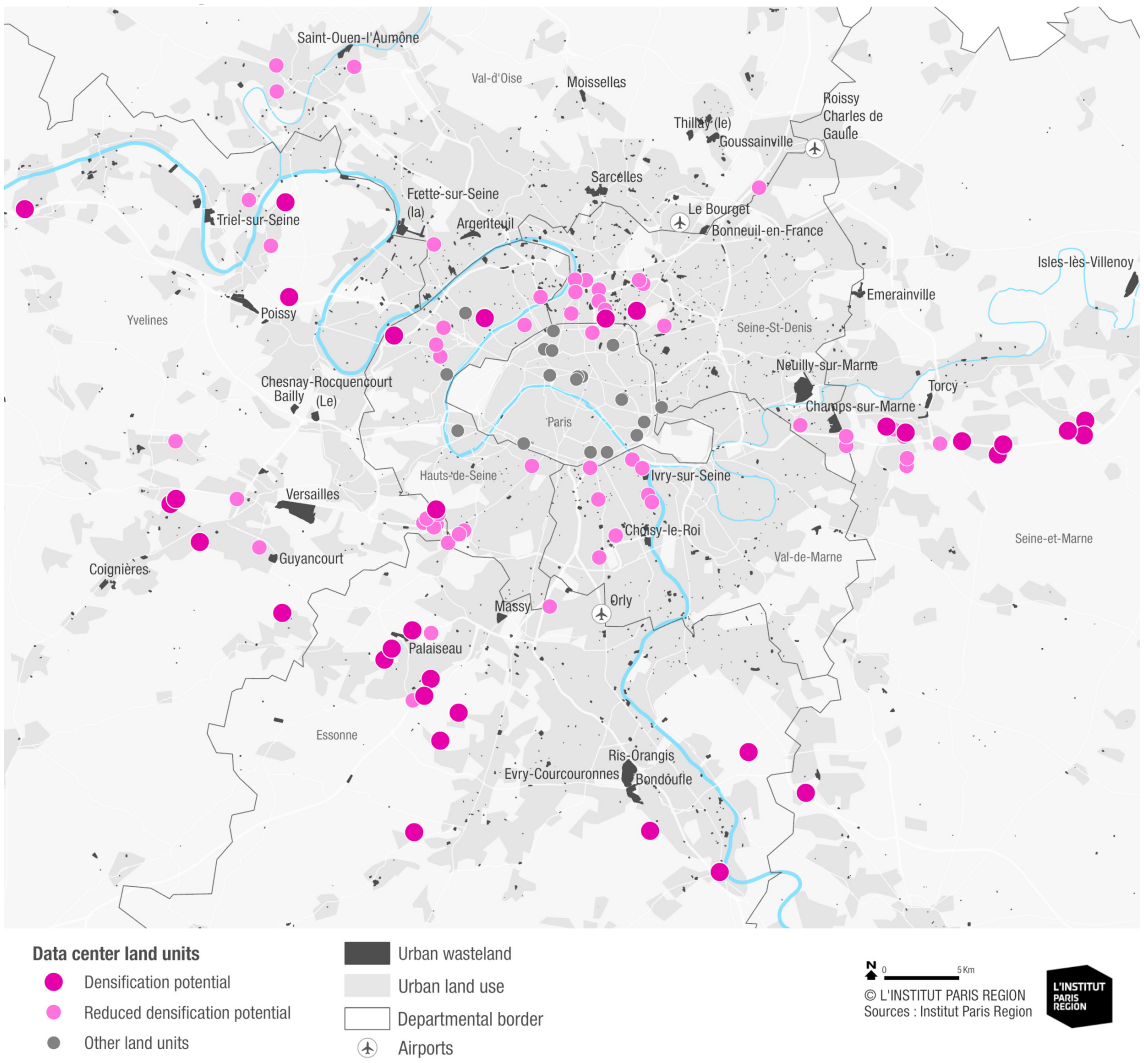
Local development

Criterion 3 : land sobriety and preservation of open land

On the territorial scale:

- Insofar as is possible, the data center project is sited in an existing data center site or on wasteland not appearing particularly relevant for other uses (industry, green spaces, biodiversity...):
  - it is installed in already urbanized zone and practices urban renewal;
  - it seizes opportunities to reuse industrial, logistics and office buildings, even existing and aging data centers;
  - following the avoid-reduce-compensate sequence, it only contributes to urban expansion in certain exception cases, and in these cases:
- it uses small plots (to build in height), in continuity with the urbanize dspace (preferably near high-voltage lines or along highways or railroad tracks);
- it favors zones with a low ecological and agricultural value;
- it strictly avoids sectors that have medium or strong protection of biodiversity and/or landscape (regional nature reserve, listed site...);
- it avoids open urban spaces (sports fields, etc.);
- it also avoids wasteland with a low mineralization rate;
- moreover, proposals for better spatial organization, requiring the moving of sites, can facilitate the dialogue between the parties involved in the project. It can then be decided to close a data center site, for example, to transform it for another use, and to better organize another zone.

DENSIFICATION POTENTIAL IN DATA CENTER LAND UNITS



On the scale of the site and the building:

- The data center project provides credible proof, in the presentation of its concrete siting modalities, that it presents an optimal density on the scale of the building and the site (land unit) and that it limits its land artificialization rate:
  - right from its design, all the construction needs, including for annex equipment (substation, basins, fuel oil storage, etc.) must be clearly identified. They are assembled and reduced to the minimum area possible, in order to limit the artificialized area;
  - the project is designed to be as compact as possible. Notably in the densest urban areas, the intensification of the operation is favored and the land artificialization rate on the plot is the lowest possible. A tall construction is to be favored, if it makes it possible to consequently generate or preserve the open and non-artificialized area;
  - if part of the project is underground, intensification of the basement area can also be encouraged,
  - the expansion and densification of the sites is to be anticipated upstream and the expansion division in several stages should be avoided, in order to reduce the fragmentation of the natural spaces present on large sites;
  - on its scale, it contributes to the demineralization of the sites that were formerly very mineralized, for example, industrial wasteland. The data center project contributes to improving rainwater infiltration, to increasing the area of open ground in the city and acts as a support for biodiversity.

EXAMPLES

Equinix IBX PA4 and IBX PA8x data centers in Pantin

Siting in a contained sector, little adapted to other uses and densification of a site already invested by a data center

Location alongside a logistics platform and surrounded by a railroad complex.
Source : L'Institut Paris Region, 2020.

The placement within the railroad network of the Gare de l'Est train station is an example of land sobriety: the sector would be little adapted to other uses, apart from logistics. Far from residential zones, the possible pollution and noise do not cause any disturbance for the population. No new land artificialization was necessary. For the first data center (PA4), a parking garage built in the 1970s-1980s was transformed. For the second data center (PA8x), a new construction was added in 2019, densifying the land unit.

The Qalway digital boiler

Maximum server distribution

Qalway digital boilers (here model QB1) supply a heating network in the city of Kankaanpää in Finland (10,000 households). Source : Qalway

The Qalway digital boiler (Qarnot Computing)[74] functions by means of a dozen computer processors that supply a single heat recovery system. Connected to optical fiber, each QBX module can supply up to 3.2 kW of power. It is possible to install several modules in series or parallel for more heat or flow. In circulating in the boiler, the water takes on calories of computing power. At over 65°C, the water can be used as domestic hot water and for hydraulic heating. Thanks to its modular system, the boiler can be integrated into different contexts, such as public buildings, offices, housing units... Making it possible to recover over 90% of the energy to heat the water circuit, this model can take on more importance in a land sobriety issue and interest more companies.

74. https://qalway.com/fr/product/chaudiere-numerique

Criterion 4 : urban integration: mixed functions

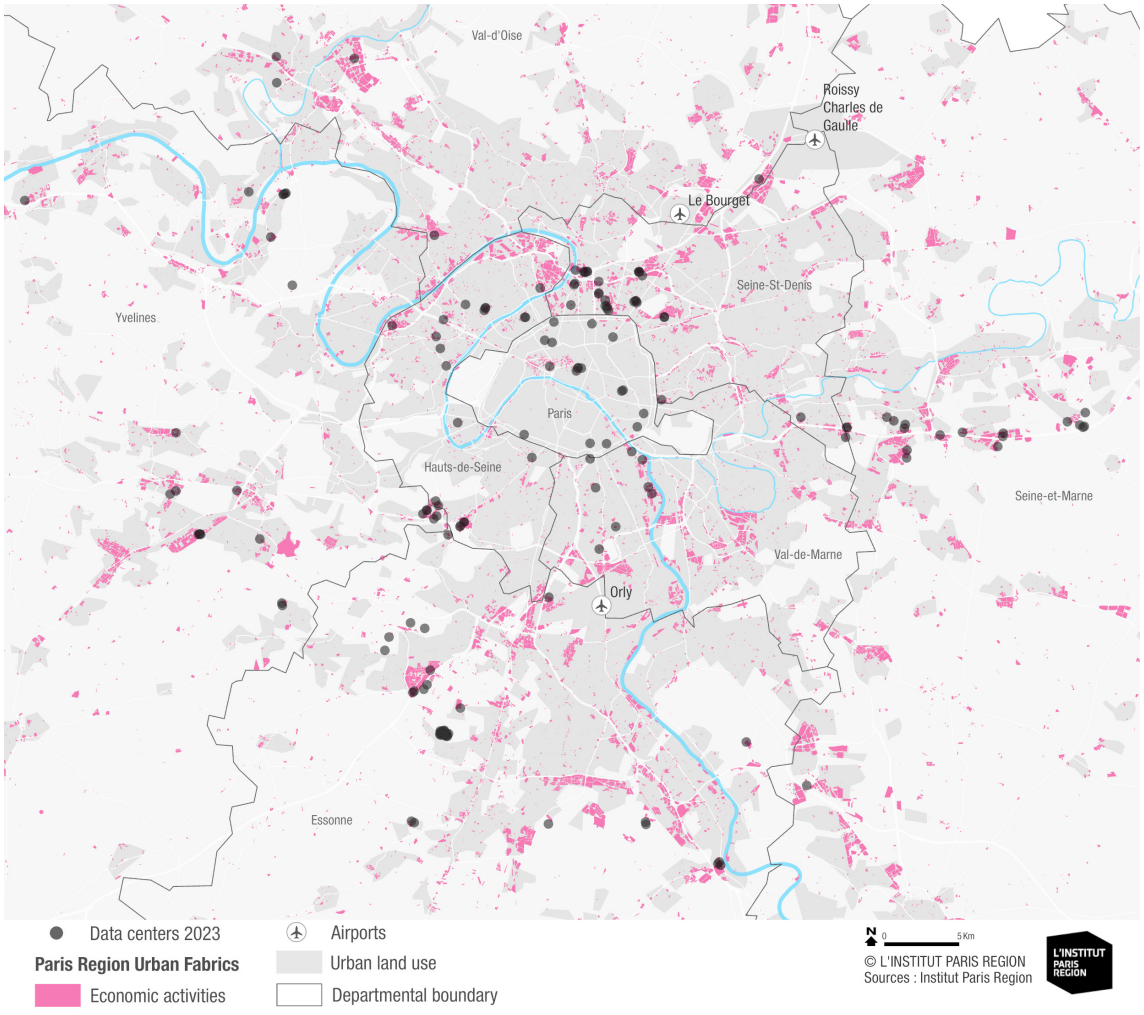
On the scale of the territory:

- Insofar as is possible, the data center project is sited in a mixed activity fabric.

On the scale of the site and the building:

- In every case, the data center project provides credible proof, in the presentation of its concrete siting modalities, that it hosts mixed or hybrid uses on the scale of its (this criteria however will not be imposed on data centers with an "OIV" (operator of vital importance) status; as far as is possible, it is installed, for example, on university campuses or shares premises with offices; the building or site therefore appears less opaque and less protected:
  - as for mixed programming, it is of the DC 01 type "The infiltrated data center," which confirms the possibility of mixing function in a single building for certain types of data centers and more specifically for small installations in a very dense milieu. In Paris, they are integrated into office buildings, even apartment houses, occupying one or more stories or technical rooms;
  - mixed programming inside a building remains complicated for security and confidentiality reasons. Alternatives can be studied on the scale of the site. The project can, for example, include a small building facing the street, which acts as an active base and that houses businesses or other functions.[78] The data center itself can be placed behind this building, farther from the street.

ACTIVITY FABRICS AND DATA CENTERS



75. For example, it is Amsterdam's policy that imposes these conditions, for the Amstel III sector.

EXAMPLES

Digital Realty (Interxion), PAR2 in Aubervilliers and Foliateam Paris Nation

Mixed functions, and sharing of premises within the same building

Buildings in which these two data centers of Digital Realty (Interxion) (left) and Foliateam (right) are located.
Source : L'Institut Paris Region, 2023

(Left) In Aubervilliers, these former hangars transformed in the 1960s house numerous companies, businesses and, since the 2000s, a Digital Realty (Interxion) data center.
(Right) This data center is located in a mixed building that also has apartments. With an IT area of 2,000 m², the data center occupies premises on three levels of this multiple-story building. It is not visible from the public space.

The Digital Reality Amsterdam Data Tower in Science Park, Netherlands

Integration of a data center into a mixed scientific campus

The Digital Realty tower in the background.
Source : L'Institut Paris Region, 2023

The City of Amsterdam has been involved for the last several years in a better spatial insertion of data centers. Since 2013, the efforts have concerned landscape integration, architectural quality, energy performance and the diversity of the programs (commercial, cultural, etc.), following the example of the Equinix and Digital Realty buildings (see photo), integrated into Science Park. On this university and corporate campus rises the Digital Realty Data Tower with 11 stories and a total area of about 16,000 m². It hosts the data of over 120 customers.[76] Aesthetic façades, reception opening onto the public space, no fences... it is notably through the city's prescriptions that this data center is well-integrated into this mixed urban environment and can scarcely be distinguished from other buildings in the Park.

76. https://www.digitalrealty.com/data-centers/amsterdam/amsterdam-data-tower-science-park-120-amsterdam

Criterion 5: urban integration : urban and lanscape insertion and architectural quality

On the scale of the territory:

- Insofar as is possible, the data center project is sited in a contained urban environment (VGV line corridors, noisy zones[77]...) that it contributes to requalifying.
- In every case, the data center project provides credible proof, in the presentation of its concrete siting modalities, that it makes sure to respect the natural, landscape and urban setting. This requires understanding the landscape and urban context in which it is located and knowing its characteristics:
  - the landscape must be part of the choice criteria of where the site is installed. If the design of the project is not compatible with the environment and cannot be modified (building height, technically required volumes), another location must be found;
  - that it aims at the least impact on the landscape possible: the views on the landscape must be preserved and "visual pollution" avoided. The global choice of the site is primordial: an isolated installation, or a change in slope in the middle of plateaus or hills is to be avoided.

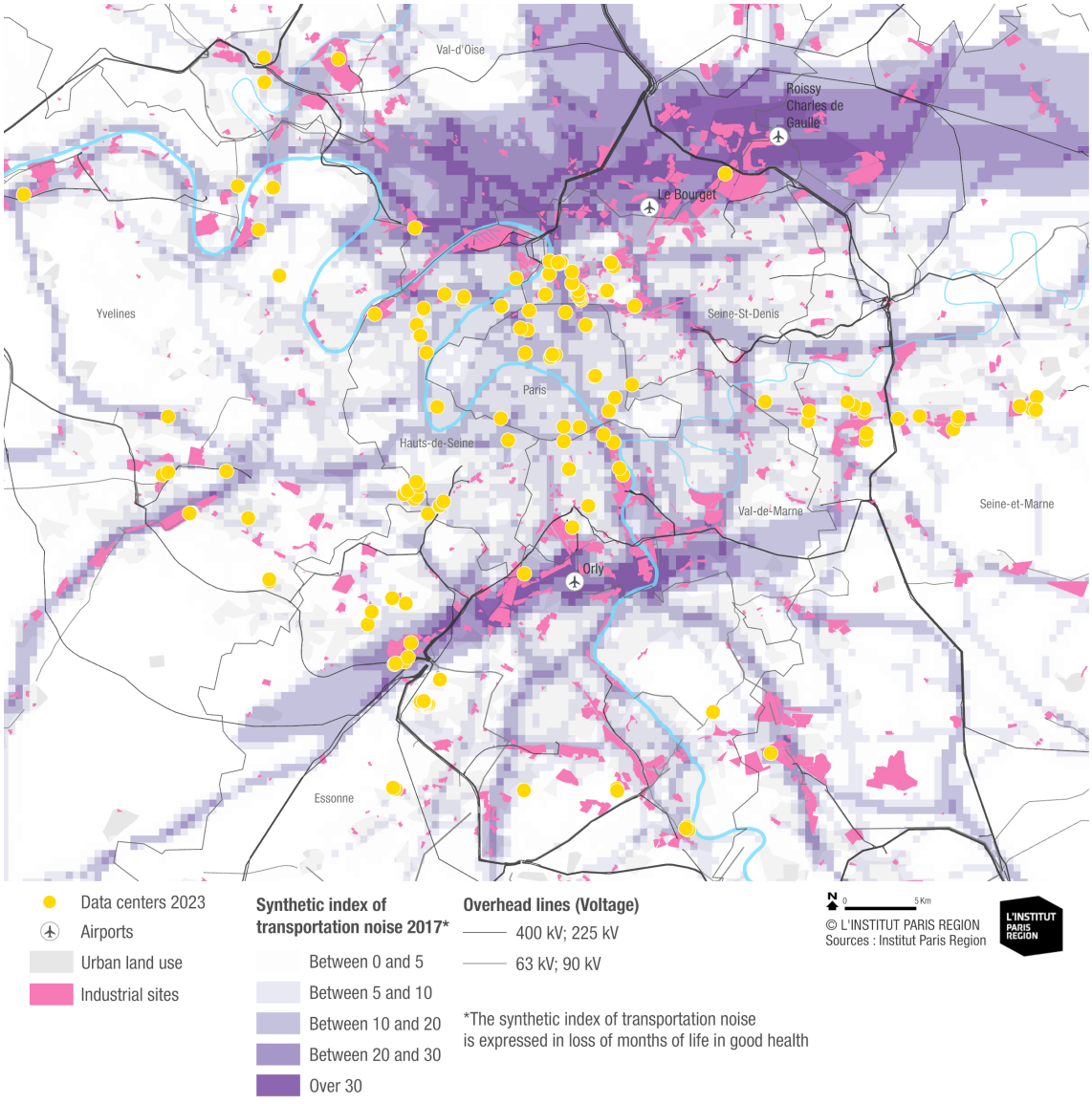
On the scale of the site:

In every case, the data center project provides credible proof, in the presentation of its concrete siting modalities, that it contributes to requalifying and/or preserving the urban and landscape environment by the development of the site:

- By the spatial organization of the buildings, fences and access roads, the project does not disturb any ecological or landscape continuities (open spaces, woods, ponds, humid zones...), notably those identified by the planning tools (like in Île-de-France the Sdrif, the SRCE, the SCoT) and/or the local urbanism plan... On the contrary, if it can contribute to restoring such continuities and consequently, for example, improve the migration conditions of animals (rodents, amphibians, birds, insects...) is to be studied;
- It limits its visual impact on the scale of the site, in using the elements of the environment, such as what is visually in the background (woods, reliefs). The limitation of the height of the building, the right positioning on the site and the accompaniment by plant or architectural elements can lessen the negative impact, notably in the rural or peri-urban space. Following the recommendations on the integration of large facilities of the Architecture, Urbanism and Environment Council (CAUE) of the department or, if necessary, of the regional park, etc.;
- The landscape development of the project corresponds to its territory, it is inspired by landscape motifs taken from the local vocabulary. It is not a question of a standard and above-ground development;
  - enhancement of the sites by plantings: instead of concealing the building by a mineral or plant curtain wall, which has a tendency to further emphasize the presence of the building, cutting off long perspectives by plantings. Being inspired by landscape structures and plant filters, such as hedges, groves and isolated trees characteristic of the territory;
- It maintains open ground and ensures better infiltration and management of rainwater;
  - reduction of the soil's mineralization rate by surface coverings, evaluating the real need in parking, delivery, road and terrace areas and reducing it to the strict minimum;
  - use of permeable surface coverings (stabilized, hollow core slabs...) when this is possible;
  - water management on the plot with a planted ditch and retention basin system.
- The data center project makes use of a visibility and adapted representability for better acceptability:
  - reduction to the minimum of fences and visible protection and surveillance systems, notably the exposure to the public space (this criterion will however not be imposed on data centers with the status of "operator of vital importance or "OIV");
- use of alternative plot delimitation solutions, such as drainage ditches ormoats instead of fences. If a fence is indispensable for security and confidentiality reasons, aiming at openwork fences accompanied by plantings. If not, studying the possibility of integrating the fence in the

77. The areas around large airports are particularly important on the map "Contained urban environment and data centers" due to their high level of exposure to the noise of transportation. It must however be stressed that a part, certainly very limited, of these surrounding areas is strained by aeronautical easements that limit the height of "obstacles" likely to be built, notably in the axis of the runways.
High (63-90 kV) and very high (225- 400 kV) overhead voltage lines are also accompanied by easements, included in specific conventions between RTE and each owner concerned (RTE is not the owner of the land located to the right of these lines and transmission towers, but only of the electricity substations) but it is especially local urbanism plans that are likely to most strongly regulate the purpose, volumetrics and siting of constructions on the lands concerned (https://www.rte-france.com/ riverains/ servitudes-lignes-electriques).

CONSTRAINED URBAN ENVIRONMENT AND DATA CENTERS



façade, on the building's ground floor;
- use of plants in delivery and parking zones, in order to reduce their visual impact;
- orientation of the building's reception area turned toward the public space;
- posting of the operator's name on the entrance.

- The project is based on a quality, diversified and ecological landscape development that also corresponds to preservation and biodiversity requirements;
- for the choice of plantings of trees, shrubs and perennials, the landscape project is based on the local plant palette and drought-resistant species;
- prioritization of mixes of plants that attract bees and arrangements that welcome insects (cavities, dead plants, straw, etc.);
- ecological management plan with late mowing;
- calling on a landscape designer at key moments of the procedure.

On the scale of the building:

In every case, the data center project provides credible proof, in the presentation of its concrete siting modalities, that it favors aesthetic, innovative architecture that respects the contextrespecting the surrounding technical restraints (electricity connection...):

- The project proposes an optimal siting and volumetrics adapted to the building;
  - functional volumetrics of the building but also adapted to the public space. By orienting the

lowest part of the building toward the street and the largest volume toward the back of the plot, the "living" spaces of the building (offices, reception, meeting rooms) are turned toward the public space;
- instead of a large spacious building with empty areas, several small volumes that correspond to needs. Very modular buildings, making it possible to reduce the global size by limiting itself to strictly necessary volumes;
- guaranteeing the circulation of cool air in the neighborhood to reduce the urban heat island effect: not blocking an air exhaust corridor (between the street and a watercourse or green space).

- The project presents a quality architecture and notably for all the building's visible parts, like the façades and openings. All the constructions (including the visible technical structures) must be taken into account in this reflection;
- respect for the built environment. It adapts to the urban fabrics and forms with the heights and forms of the existing architecture, notably following the alignment of the façades. It contributes to enhancing its built environment;
- as in the DC 02 and DC 04 "Converted data center" types, the preservation of the old built environment is to be prioritized, notably when the building presents an interesting heritage (former hangars, industrial buildings), but also the issue of economizing materials and reducing CO2 emissions. The preservation of small heritage elements (elements of the façade, the roof, signs, glazed areas, etc.) must at least be considered, even if the structure must be exchanged. This makes it possible to guarantee visual continuity in its fabric;
- a treatment in continuity with the built environment is necessary for the façades. The use of quality materials and finishings is also necessary, following local rules on colors and materials.

EXAMPLE

Equinix AM3 and AM4 and Digital Realty Data Tower in Science Park in Amsterdam, Netherlands

Architectural quality and landscape insertion

In Science Park of Amsterdam, the Equinix (left) and Digital Realty (right) data centers were given specific façade and volumetric treatments. The reception area is turned toward the public space, the fences were reduced or integrated into the façade. Source : L'Institut Paris Region, 2020.

Like the Digital Realty Amsterdam Data Tower (right, project described on p. 73) and a few meters away from it, this Equinix building (left)[78] is located on the same science campus. It shows the same requirements that the City of Amsterdam instituted and is one of the rare and principal landscape insertion and architectural quality projects in Europe. The Equinix AM3 and AM4 data centers are surrounded by a ditch filled with water, which replaces the fence. The Green Data Center Award distinguished, in 2013, the first building erected in 2012. Connected by bridges, the second building was inaugurated in 2017. With 4,200 m² of colocation spaces, a gross floor area of 24,000 m² and a maximum height of 72 meters, the buildings are visible from the A10 highway. Divided into 12 stories, it is enveloped by an openwork façade that emphasizes its verticality.

78. https://www.equinix.fr/data-centers/europe-colocation/netherlands-colocation/amsterdam-data-centers/am3

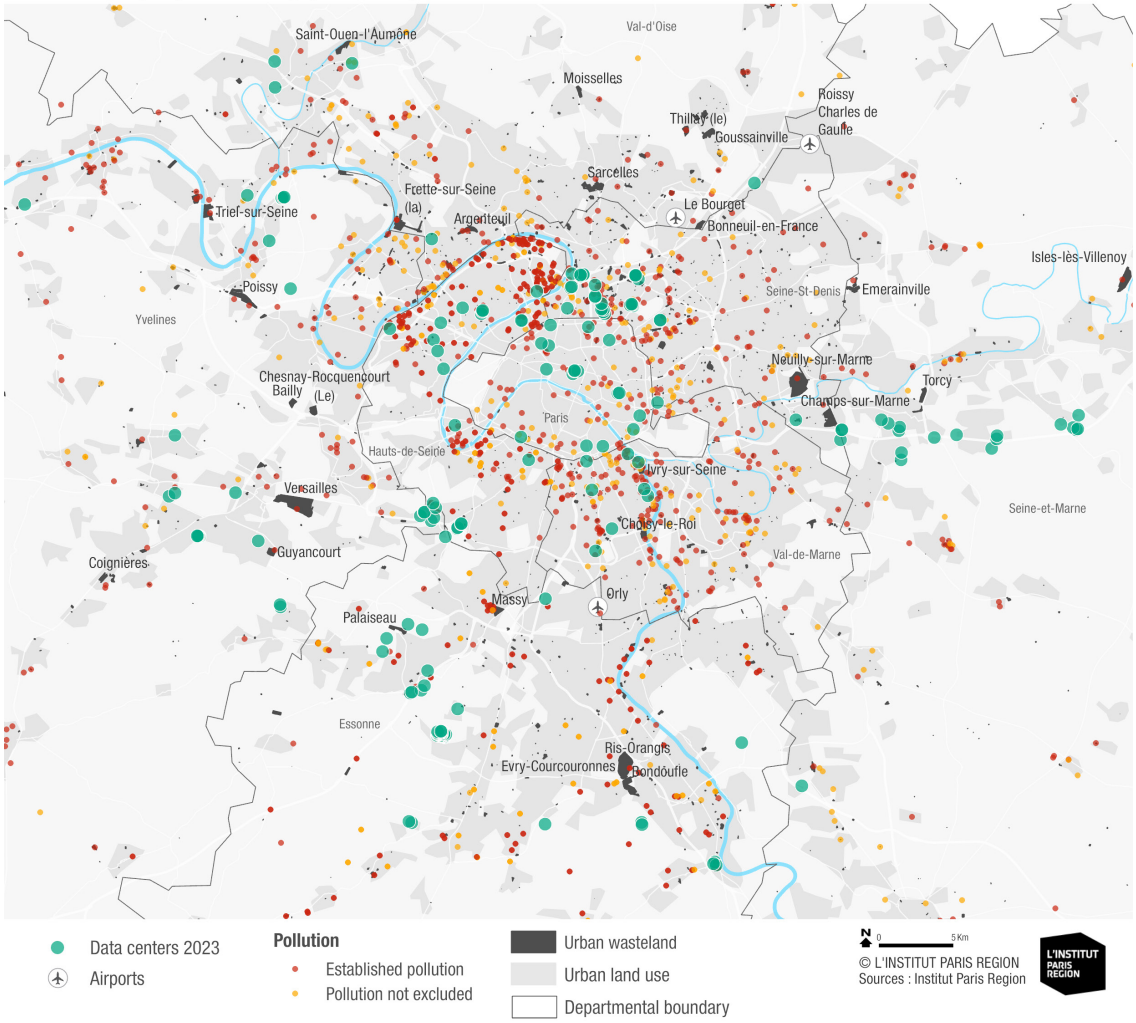
- Insofar as is possible, the architecture is also innovative in terms of an eco-design and biodiversity effort (cf. criterion 11);
  - a larger porosity of the façade is proposed, instead of glazed and smooth façades. The data center building can have nesting places for birds and insects. More porous, it will also permit the vegetation to invest the building: moss, lichens, climbing plants can more easily attach themselves and contribute, on a very local scale, to preserving biodiversity and cooling.[79] Moreover, a façade with openings can provide natural ventilation;
  - using the same logic, planted roofs can be a solution in certain places, also permitting, on a very limited scale, storing rainwater and reducing the urban heat island effect.

Risks and pollution

Criterion 6: resorption and prevention of pollution

- As far as is possible, the data center project is sited on polluted soil that it helps depollute;
- In every case, the data center project provides credible proof, in the presentation of its concrete adaptation modalities, that it limits the risks of soil, water and air pollution (notably linked to backup generators).

POLLUTED (OR POTENTIALLY POLLUTED) SITES AND SOIL



79. Pioneers in the incorporation of these conditions in their framework documents, it is the cities of Amsterdam and Haarlemmermeer that mentioned these rules to favor biodiversity on the data center sites.

LCP-Data Village project (project owner) in Corbeil-Essonnes

EXAMPLE

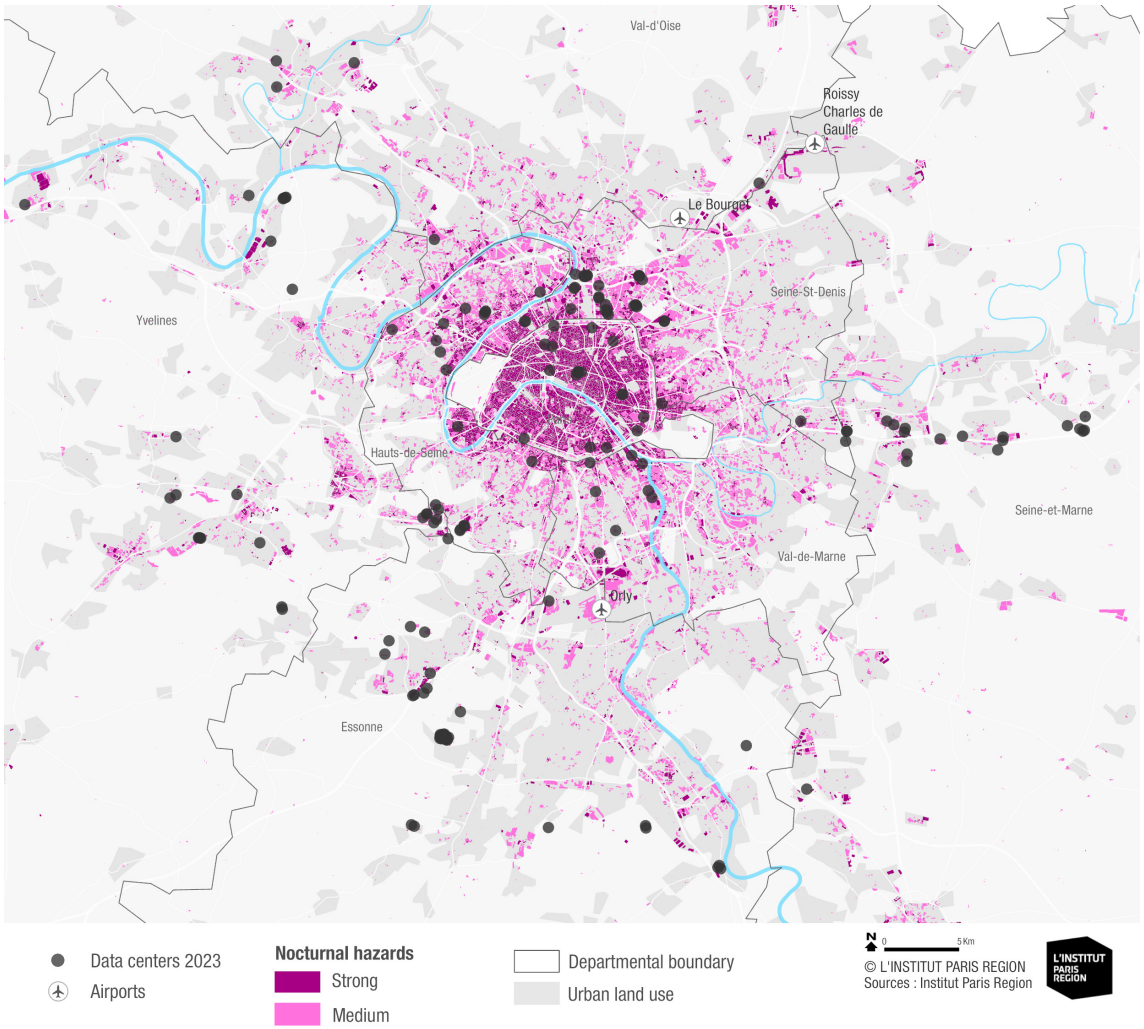
Resorption and prevention of pollution

This project concerns the construction of a campus of three data centers (Data Village Paris-Essonne), and a total area of about 14.6 hectares, on the territory of the Le Coudray-Montceaux and Corbeil-Essonnes communes. This former industrial site was operated until 2017 by the Altis Semiconductor company. Depolluting this site was carried out between 2019 and 2021 with the aim of preparing the site for the data center project. The opinion of the MRAe d'Île-de-France[80] mentions that this work made possible "the demolition of 50,000 m² of buildings, the treatment and removal of 45 tons of asbestos and the transfer of about 25,000 tons of polluted earth to the adapted treatment centers, including 3,000 tons by waterway." It should be pointed out that the data center can in its turn also contribute to soil pollution. A pumping and treatment station for water from the Seine has moreover been planned. After having used it for the servers' cooling system, the water will be discharged into the Seine, which can potentially be another source of pollution.

Criterion 7: resorption and prevention of the urban heat island effect

- Insofar as is possible, the data center project is sited in a sector with a low urban heat island effect.
- In every case, the data center project provides credible proof, in the presentation of its concrete siting modalities, that it does not contribute to the urban heat island effect through the discharge of waste heat into the neighborhood's atmosphere.

URBAN HEAT ISLANDS AND DATA CENTERS



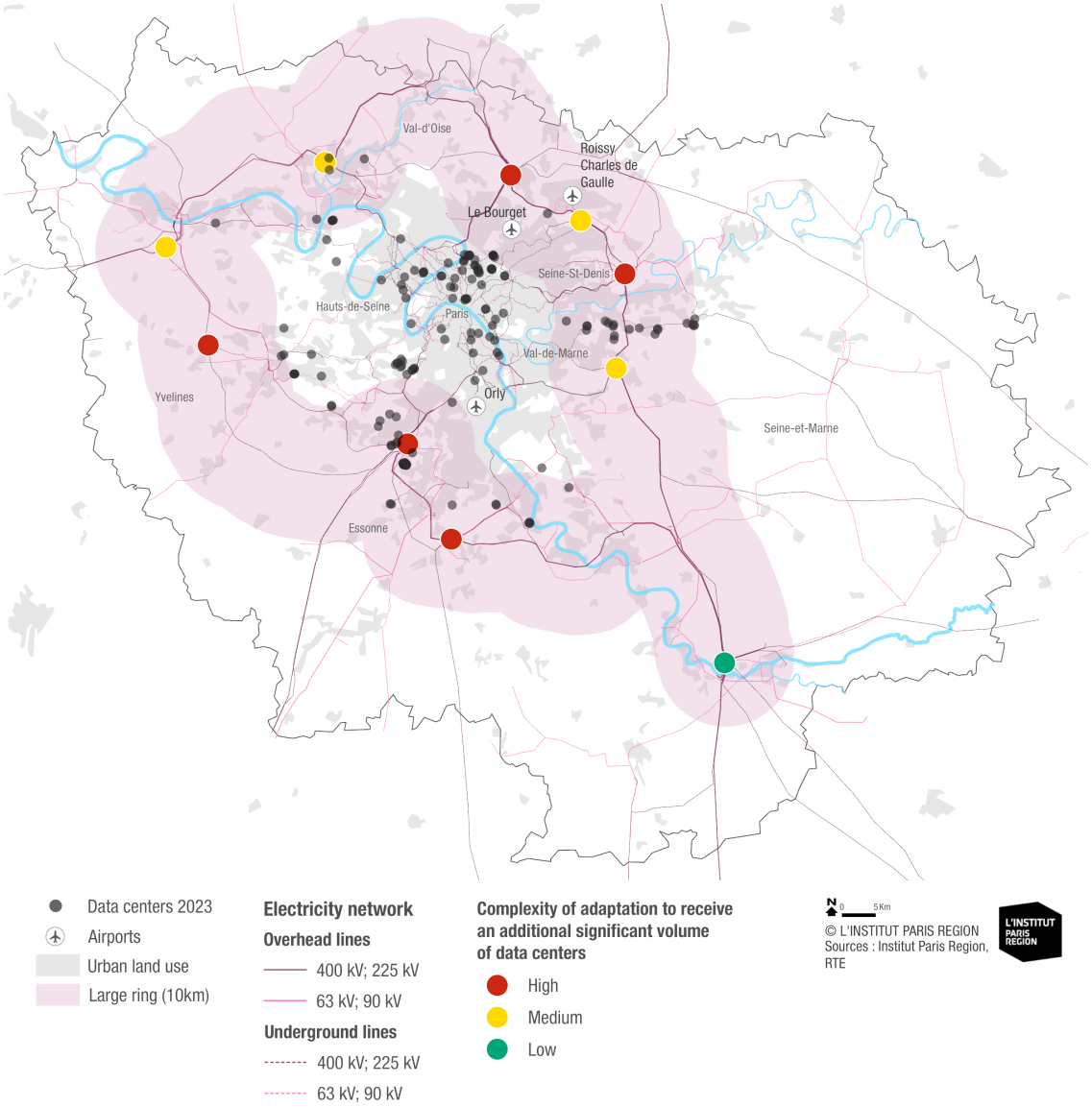
80. Notice no. MRAe APJIF-2022-022 dated March 30, 2022 on the construction project of an IT data hosting center in Le Coudray-Montceaux and Corbeil-Essonnes.

Energy

Criterion 8 : resilience of the regional electricity system

- Insofar as is possible, the data center is sited outside sectors in which the electricity network is under pressure or the adaptation of this network is of particular complexity and does not evict or block other projects (reindustrialization, urban services, urban projects, hospitals...).
- In the case of the creation of a zone dedicated to receiving several large data centers, the complexity of the adaptation of the electricity network must be particularly taken into account.
- In every case, the data center provides credible proof, in the presentation of its concrete siting modalities, notably those discussed with the network managers and the energy regulation commission:
  - that in the short term, its demand for power will be made within the limits of the electricity availability of a substation;
  - that in the medium term, for additional demands for power, it contributes to reinforcing the network and freeing up available electricity greater than its needs, that it anticipates its later expansions and presents growth scenarios to the network managers.

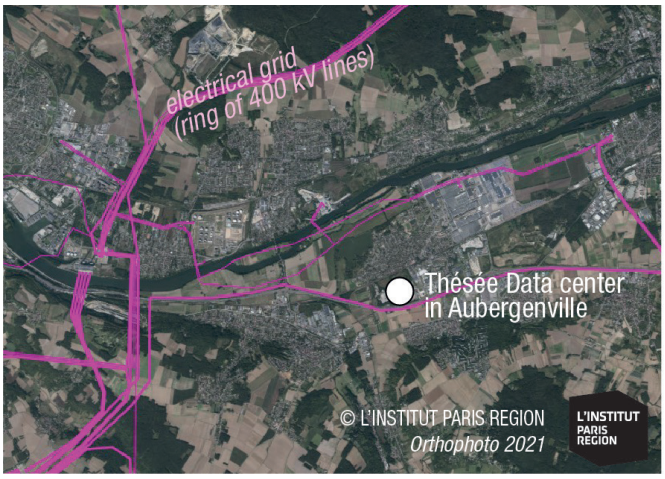
COMPLEXITY OF THE ADAPTATION OF THE ELECTRICITY NETWORK (COSTS, TIME FRAMES, SCOPE OF WORK ON SUBSTATIONS)



EXAMPLE
Criterion 8

Thésée in Aubergenville

Data center located outside the very contained zone of the Paris conurbation



Located near the 400/225 kV ring of the Île-de-France electricity network that brings electricity to the capital. It is notably around this 400 kV ring and the transformation substations that RTE signals development potentials with fewer constraints than in the dense zone. The Thésée data center is located near the Mézerolles transformation substation on which capacities could still be mobilized at the time.

Source : L'Institut Paris Region, 2021.

Criterion 9 : energy sobriety and efficiency

- Insofar as is possible, the data center project is sited in a sector with good public transportation services.
- In every case, the data center project provides credible proof, in the presentation of its concrete siting modalities, that it limits its energy consumption (electricity, fuel oil…):
  - by presenting a very-high performance energy effectiveness indicator (PUE),
  - by using free cooling instead of cooling units.

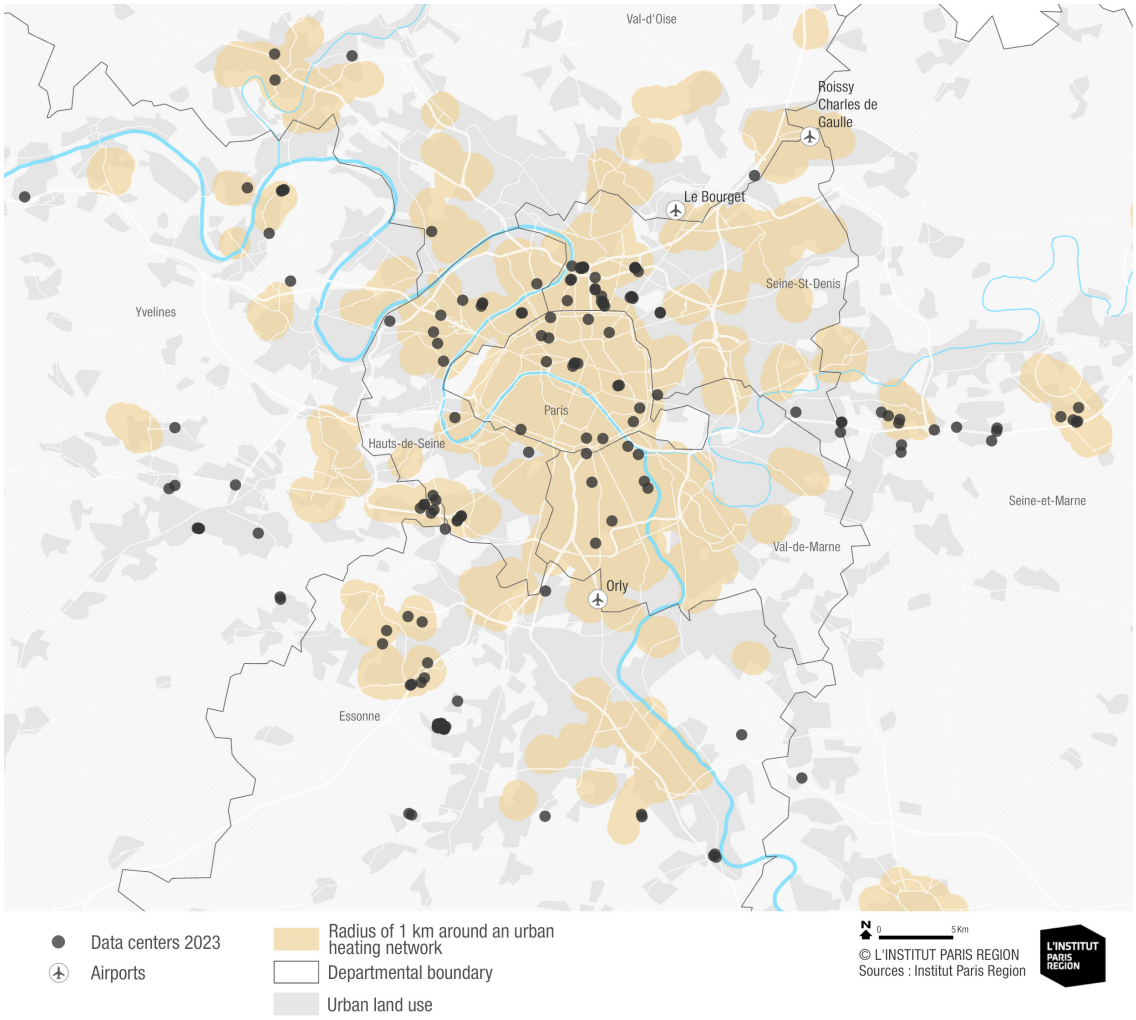
To go further than simply the energy efficiency considered by the PUE, the Energy Reuse Factor (ERF) and Energy Reuse Effectiveness (ERE) indicator[81] includes heat reuse:
When the data center is equipped to reuse the energy from it machine room, the measurement of the energy reused E_{-REUSE} makes it possible to calculate two additional ratios introduced by The Green Grid.
The ERE is the ratio between the difference in the quantity of energy consumed by the data center and the energy reused, divided by the energy consumed by computing: $ERE = ((E_{-DC} - E_{-REUSE}))/E_{-IT}$.
If the data center is not equipped to recover the energy emitted by its equipment, the ERE is equal to the PUE. If not, it is lower than it. It makes it possible, for example, to take into account the heat drawn from the server room that is not dissipated into the environment, but reinvested to heat the building.
The ERF is the ratio between the energy reused E_{-REUSE} and the total energy consumed b the data center E_{-DC}. It is an indicator without a unit, its value is between 0 and 1. The standardization of this indicator is being studied by the ISO/IEC.

81. The ISO standard: https://www.iso.org/obp/ui/#iso:std:iso-iec:30134:-6:ed-1:v1:en

Criterion 10 : use of renewable energies and recovery

- Insofar as is possible, the data center project is sited in a sector favorable to the development of renewable energies and recovery:
  - in a zone authorizing the presence of photovoltaic panels on rooftops,
  - near an existing heating network or an urban project likely to develop its own heating network.
- In every case, the data center project provides credible proof, in the presentation of its concrete siting modalities, that it includes renewable energy production (solar panels...) or waste heat recovery systems:
  - in being its own renewable energy supplier, produced and consumed onsite (example: setting up a renewable energy self-production system such as photovoltaic panels on the roofs, shade structures on parking lots);
  - in recovering the heat produced by the servers (waste heat), employed for uses outside the data center (heating and/or hot water in residential/office building and public facilities; for new technologies: cold water creation, energy creation, heat for industry) using the connection to an existing or future urban heating network. For waste heat recovery to function, the data center should be close (distance below or equal to 1 kilometer) an urban heating network, and that the local administration concerned and the technical syndicate provide their support for the project. Local use is favored. Very large data centers can provide more solutions and be located farther from the heating network.

URBAN HEATING NETWORK AND DATA CENTERS

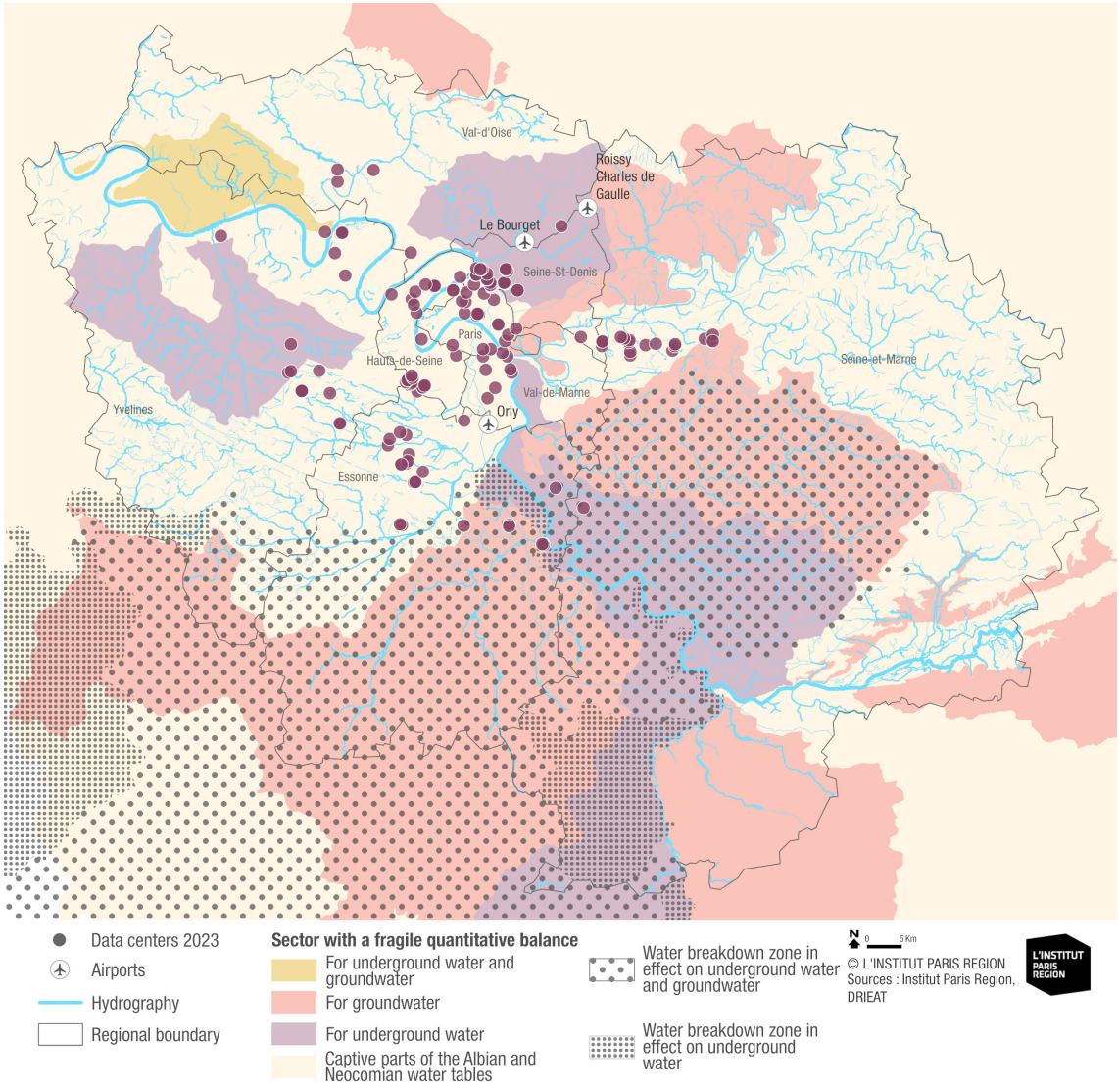


Water and materials

Criterion 11: water and materials sobriety

- Insofar as is possible, the data center project is sited in a sector that does not have medium or strong quantitative pressure on the water resource.
- In every case, the data center project provides credible proof, in the presentation of its concrete siting modalities:
  - that it presents a very high-performance water usage effective (WUE);
  - that it has a recovery and reuse system for rainwater and/or graywater;
  - that it does not need to draw deep water and does not need to renew the water in its closed circuit for cooling;
  - that it works for sustainable management of construction materials
- by prioritizing the reuse and recycling of materials and supports research on this subject;
- by using geo-sourced and bio-sourced materials (terra-cotta bricks, wood, etc.);
- by prioritizing a modular and reversible design for the building, which makes it possible to be closer to real needs, generate economies of scale and facilitate a later dismantling of the building.

PRESSURE ON THE WATER RESOURCE



EXAMPLE

Google, Douglas County, outskirts of Atlanta, Georgia, United States

Cooling with graywater

This Google data center in Douglas County in Georgia has functioned since 2012 with graywater. Domestic or recycled water then is used for cooling the data center, after treating this graywater, which functions by means of dedicated and outsourced equipment. What is not evaporated in these towers will once again be treated before being discharged into the river.

As of this date, examples of the change in this cooling system remain marginal, including with Google. Since 2022, the American company has stated that it made its annual water consumption for its data centers transparent. It amounts to about 4.3 billion gallons of water (16.3 million m^3, which corresponds to the annual drinking water consumption of about 255,000 French people[82]), of which 971 million gallons (3.7 million m^3) outside the United States[83]!

4.3 THE LOCAL URBANISM DOCUMENTS THAT SERVE THE INTEGRATION OF DATA CENTERS

Between regional strategy and analysis grid of the concrete siting projects initiated by the operators, the local urbanism documents – in France, local urbanism plans (PLU or PLU(I)), territorial coherence guidelines (SCoT), etc. – have a role to play in anticipating data center siting projects, maximizing their positive impacts and minimizing their negative effects. In different urbanism documents in Europe, what counts is the consideration of the data center subject at all the different planning levels and, of course, the dovetailing of these documents.

We can sketch a list of the principal issues, among those identified in Part 3 of this report, that a a local urbanism document, like the PLU(I) in France, is likely to help take into account:

- integration of the vegetation;
- limitation of rainwater discharge on the plot;
- respect of an open ground coefficient and/or Biotope;
- alignment of façades on the street;
- limitation of the height of the buildings (with specific problem of taking possible stacks into account), notably depending on the surrounding built environment;
- preservation and reuse of the existing buildings;
- encouragement of the installation of solar panels on the roof;
- encouragement of waste heat recovery;
- bioclimatic design of the constructions.

82. According to the French Ministry of the Ecological Transition and Territorial Cohesion, between 2010 and 2018, the annual volume of water consumed is estimated at 4.1 billion m3 In metropolitan France, which represents 64 m3/inhabitant.
83. https://www.gstatic.com/gumdrop/sustainability/2022-us-data-center-water.pdf

4.4 FAVORING THE EMERGENCE OF A REGIONAL PUBLIC GOVERNANCE ON DATA CENTER DEVELOPMENT

Instituting and leading a collective of public and parapublic data center actors

Over the last few years, exchanges between public and parapublic actors aiming at reconciling data center development and territorial development and environmental issues in Île-de-France have multiplied, in variable contexts and configurations.

- Since 2015, various studies and Notes rapides on the subject have been produced by L'Institut Paris Region[84] (on its own behalf or for the ADEME, and for RTE and Enedis) ;
- Working groups organized between 2020 and 2021 by Choose Paris Region, with public of a practical guide for elected officials in Île-de-France[85];
- Visits to data centers organized by certain operators (Digital Realty [Interxion], Data4...) for public and parapublic organizations;
- Working meetings organized by the Regional and Interdepartmental Division for the Environment, Development and Transportation of Île-de-France (DRIEAT) on the orientations for examining applications for approval with a reference sheet as a result[86];
- The publication of an explanatory note from the MRAe d'Île-de-France on the siting of data centers[87] that is based on its many opinions put forward on the projects.

These exchanges have made it possible to sketch the outlines of a collective of public and parapublic data center actors in Île-de-France.

It will concern, on one hand, instituting this collective around an initial core of members notably including the services concerned in the DRIEAT, the Environmental Authority, the ADEME, the Île-de-France region, L'Institut Paris Region, etc. and can gradually broaden to other actors (Choose Paris Region, Efficacity, RTE, Enedis, Airparif...). When the same organization includes several entities that are concerned, it can be useful to explicitly consider each one as a collective member. The question will then be to give this collective a name.

84. Cf "Resources;"
85. "Les datacenters : alliés de la transition énergétique et du développement des territoires en Île-de-France. Guide pratique à destination des élus franciliens," Choose Paris Region, January 2022
86. "Fiche repère Instruction des demandes d'agrément relatives aux centres de données," DRIEAT, March 2022
87. "Note d'éclairage. Les centres de stockage des données," MRAe d'Île-de-France, June 2022

It will concern, on the other, leading this collective, notably through regular plenary sessions held at least twice a year, for example, in May and November, and periodic sessions making it possible to gradually adjust, through experience, the scope of the missions allocated to this collective (see below): zoom on a specific regulatory evolution, review of the data center project sitings underway, exchanges with the local public actors (communes, inter-communal structures...) or with the private actors (operators...), presentations of studies conducted by members of the collective or third parties...

Creating a regional data center observatory in Île-de-France

One of the vital missions of the collective can be the creation of a data center observatory in Île-de-France, to:

- Regularly update, share and disseminate knowledge of all the data center "objects" in the Paris region (update of the Database of data centers in Île-de-France by L'Institut Paris Region, refinement and diversification of typologies, follow-up of energy consumption of the data centers in the framework of ROSE (Statistical Observation Network of Energy and Greenhouse Gas Emissions of the Île-de-France region...);
- More generally, improving, regularly updating, sharing and disseminating knowledge of the Paris region data center "market" and its position on the domestic, European and international markets;
- Boosting, coordinating and/or promoting studies on the data center "ecosystem" in the Paris region (operators, subcontractors, customers, local administrations...).

This observatory will be the trusted third party in a position to overcome the fears of data center operators in the availability of data concerning them (electricity, water, filling...), but also to better identify enterprise data centers. One of the major obstacles to the exhaustive understanding of siting data centers and anticipating the consequences of better conducting the necessary transitions and adaptations is the opacity of reliable and growth expected in the years to come, has become a regional subject that requires its own strategy. This could become a central reference that guides the projects in the territories and that provides conditions for integration on the local scale. It is founded on a certain number of preliminary studies, notably on electricity and land availability.

- Helping the local administrations (see Part 4.3): the collective of public and parapublic actors

accompanies the local administrations in the consideration and supervision of the data center subject in their local urbanism documents.
- Consolidating and sharing the shared analysis grid (see Part 4.2): the data center project analysis grid becomes a joint tool between the public and parapublic actors to guide the siting of data centers on different scales. Each siting project is given a score depending on its performance vis-à-vis the different criteria and sub-criteria. It can prove necessary that the collective of public and parapublic actors adapt this analysis grid over time. Shared with the project initiators, the grid also becomes a guide for better designing projects upstream.

Improving the accompaniment of siting projects

One of the essential missions of the collective can also be improving the accompaniment of data center siting projects by the public and parapublic actors, in order to both increase their quality and reduce the time frames:
- By sharing knowledge of the siting projects as soon as their existence is known, then in the framework of reviews on the data center siting projects underway;
- By sharing knowledge of data center siting procedures and by collectively endeavoring to better coordinate the different components of these procedures, for example, between the environmental authorization alone and the environmental component of the application approval;
- By ensuring that the territorial administrations as well as the actors in the data center sector (France Datacenter, operators, consulting groups in specialized corporate real estate) are, upstream, oriented toward the regional contacts the most likely to accompany them in their projects;
- By establishing a shared analysis grid of data center siting projects in Île-de-France (see Part 4.2) that notably combine the questions "where?" and "how?";
- By identifying complementary actors that can help co-build the most virtuous projects between the territorial administrations and private actors (for example, by identifying a "trusted third party" for waste heat recovery projects);
- By creating attractive conditions (internet service, electricity availability, land prepared following the regulations) for data center projects near urban heating networks with the possibility of developing a business plan so that the data center's waste heat can be bought for urban heating.[88]

Becoming proactive on the national, even international level

Finally, regarding the heavy concentration of data centers and data center siting projects in Île-de-France, the collective will be a legitimate structure for becoming a genuinely proactive on the national level:
- By contributing to the evolution of the legislation and taxation: evolution of statistical (dedicated NAF [activity] code...), regulatory (ICPE categories [installations classified for the protection of the environment], approval categories...) and urbanistic (for the purpose and use in urban planning) nomenclatures, and clarification through the tax administration of classification modalities for locales of the data center type for the different taxes in order to avoid competition distortions between structures and identification of the impacts on the local administrations' resources of a possible homogenization.
- By contributing to the promotion of technical solutions, notably concerning development and the environment, co-built with the private actors of the data center ecosystem in the Paris region, concerning, for example:
  - the search for environmental certificates or labels, possibly with a target level (LEED Gold, or BREAM Outstanding);
  - the carrying out of studies on making waste heat available and their mandatory public dissemination;
  - the acceptance of a higher operating temperature in data centers to reduce cooling needs;
  - the improvement of cool air circulation (confining warm aisle/cool aisle);
  - the optimization of cool air production by free cooling/free-chilling;
  - the non-increase in energy density (power consumed per m²) of the open spaces;
  - the design of data centers: **modular,** to scale its operation according to the demands: opening of IT and technical rooms by section according to the filling rate, making it possible to lessen the effects of over-reservation of power, blocking other customers and oversizing the electricity infrastructures; **reversible,** so that the building can change function at a later date.
- By contributing to the emergence, leadership and

88. As was done in Sweden with the Stockholm Data Parks. See; "Data centers : anticiper et planifier le stockage numérique," L'Institut Paris Region, May 2021.

technical enlightenment of a national debate on the development of data centers in France on the questions connected to it (digital sobriety, digital sovereignty, energy sobriety, land sobriety...).

CONCLUSION

The development of data centers in Île-de-France is accelerating and even risks soaring in the next few years, according to the current projections of the ADEME and the ARCEP.[89] The knowledge of the projects underway by the electricity operators, as well as by the Regional Mission of Environmental Authority (MRAe) of Île-de-France, confirms the projections. This growth could have considerable impact on electricity consumption and the robustness of the electricity network, in a context of increasing needs, notably connected to the electrification of mobilities, and the uncertainties on production capacities (see RTE scenarios for 2035). Without a shared estimate of global needs and a coordinated breakdown of data centers, the network managers will find it difficult to meet, in acceptable time frames, the demands of the largest consumers. Competition for access to energy risks being accentuated, notably in certain dense zones where consumption is already heavy. The creation of new electricity infrastructures will be necessary, at the price of considerable costs for the public and a significant consumption of space.

This growth will also have repercussions on land in the Paris region and urban expansion dynamics and the artificialization of farmland, even forests, and more broadly on natural resources. Real estate development pressure on already urbanized land, as well as on activity fabrics being renewed on wasteland, will become even greater, and the eviction effect risks concerning certain economic activities that are among the most vulnerable. This competition could even occur between data centers and facilities, housing and green spaces, as we have learned by observing metropolises that have seen growth dynamics higher than those observed until now in Île-de-France.

In Saint-Denis, housing under construction faces two Digital Realty (Interxion) data centers, which have been in operation since the late 2010s. Source : L'Institut Paris Region, 2023.

The pressure on the water and materials resources is comparable to that which we have just cited. The global impact of risks and pollution produced by data centers on human health remains to be studied (noise, for example), but certain aspects are already well-known, such as the risk of fire[90] or the overheating of cities (waste heat released into the environment and urban heat islands effect). In a conurbation that is being transformed and densified, public health and well-being issues must remain primordial. In the Plaine sector, in Saint-Denis and Aubervilliers, the former industrial fabrics have entered a new transformation phase. Today, new housing is being built just opposite the data centers installed in the 2010s (photo opposite). The consideration of these subjects is therefore not necessary solely for new projects, but also concerns existing data centers.

Another issue that must also be stressed is the necessity of holding a debate on the "cluster vs. dissemination" subject for which a table in this study recapitulates the advantages and drawbacks. Cluster does not mean urban expansion but transformed, planned over the long term, of the existing with intelligent management of land development opportunities.

Increasingly efficient, the data center sector is at the cutting-edge of technology, but is also judge and jury insofar as, until now, it regulates itself, through, for example, the Climate Neutral Data Center Pact or the European Code of Conduct.

But these frameworks are often not very ambitious in terms of urban integration, architectural and landscape quality and especially land and energy sobriety. Data centers can be relatively flexible and be installed in different urban fabrics, in mixed buildings, and even in a basement (from a former bomb shelter in the 15th arrondissement in Paris to the former limestone quarries in Saumur)... but the most recent constructions in Île-de-France tend more toward very large projects in urban expansion. The question is therefore one of encouraging and shedding light on the coordinated action of public actors in the Paris region to make it possible, not to curb data center development, but to organize it, by minimizing its negative impacts and maximizing its positive effects, on the scale of each siting project in the same way as that of the sector's regional development.

89. ADEME and ARCEP, "Évaluation de l'impact environnemental du numérique en France," 2022-2023..
90. VH fire in Strasbourg considered a "special fire" by the firefighters: https://datacenter-magazine.fr/le-sdis-du- bas-rhin-a-publie-un-pex-sur-lincendie-du-datacenter-dovh-a-strasbourg/

ANNEX

How was the data center database of L'Institut Paris Region built?

Despite years of research, the data center market remains relatively opaque. As of this date, important data is lacking in a complete database. Few operators disseminate information on their sites (available notably for public, research or colocation data centers).

The BDD inherited work begun by L'Institut Paris Region (IAU Île-de-France at the period) in 2014 on the issues in flood zone issues. In 2015, the database was used and enriched in the framework of the study "Chaleur Fatale" ["waste heat"] steered by the ADEME and in 2019, in the framework of the work of the report "The spatial and energy impact of data centers on the territories."

In April 2023, the BDD of L'Institut Paris Region contained 175 data centers. However, only 168 have a sufficient information level for the analyses presented in this report. Our database (BDD) includes very different data centers: colocation and cloud (Data4, CyrusOne, Telehouse, Scaleway, Equinix, Digital Realty, OVH...), research (universities, laboratories), public data processing (Ministry of the Economy), banks and large companies (Atos, EDF, IBM...) and telecoms (SFR, Bouygues, Orange...). Sometimes, several data centers are present on the same site, the same land unit (like Data4 in Maroussis, Equinix in Saint Denis...), we have identified 115 in Île-de-France.

What is counted as a data center in our database?

One point of our BDD generally corresponds to the data center as announced by the operator. Sometimes, one or more operators show several data centers in the same building. All the data centers are then counted individually, except when it concerns a building that has several "data halls" and in which the operator has only announced a single data center (example: CyrusOne project in Wissous). The BDD includes sites in operation and those in the project stage, but also those that have closed and abandoned projects.

The sources:

- Notice of the environmental authority; partners of L'Institut (notably DRIEAT); field visits; Presse ; counting of colocation data centers in the world (Cloudscene, Resadia or Resacloud) or in France (Global Security Mag); data center operators.

The database fields:

- Data entered: name, address, INSEE code, data center manager, state of progress, sector of the manager and the customer (public/private), initial purpose of the host building, programming of the building, current use and initial use of the building, land use category (11 categories). An estimate of the building's construction period was done based on aerial photos.
- Data partially entered: height and footprint of the building (based on the BDD's topography), number of stories, power, IT area and total floor area, date of the data center's service startup, use of waste heat, ICPE system, website of the operator.
- Data extrapolated: L'Institut Paris Region drew up extrapolation formulas to obtain the missing figures on the power in MW, the IT area and the floor area when one of the three variables was available: *Ratio m² IT/m² SDP = 0.5.*
- *Power in MW = (m² IT x 2.65)/1,000 (2.65 corresponds to the average ratio of cases for which kW and m² IT were known).*

Resources

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