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THE SPATIAL AND ENERGY IMPACT OF DATA CENTERS ON THE TERRITORIES.

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With Laurent Lefevre

Synthesis of the ENERNUM project

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Observations and challenges

What occurs behind the scenes of the smart city, big data and digital optimization is incarnated in the most visible but nonetheless very discreet fashion by the growing footprint of data centers on urban as well as rural, metropolitan and semi-urban territories. Current growth prospects of the digital sector,[1] despite the limits put forward (land and rare metal shortages and pollution from extractive industries,[2] energy unsustainability[3]), and the lack of solid foundations for certain of these projections, obliges us to reconsider our uses and their impacts on the territories and energy systems toward digital practices characterized by more restraint and degrowth.

1- Data centers could represent 13% of worldwide electricity in 2030

A 2015 study by Anders Andrae and Tomas Edler of the Huawei R&D center in Stockholm[4] estimated that the digital sector consumed 7% of worldwide electricity in 2013,[5] or the power of 210 nuclear reactors in continuous operation (for its production and consumption phase). The data centers themselves represented 2% of the worldwide total, or 420 TWh or 60 nuclear units in continuous operation. Their projections reach a maximum of 13% of worldwide electricity consumed by data centers in 2030, and 51% for the IT sector in its totality, or respectively 1,130 and 4,400 nuclear reactors. The digital working group of the think tank The Shift Project recently revised this worst-case scenario downward but estimates nonetheless that the digital sector could represent 25% of worldwide electricity in 2025 (5% for data centers), without giving an opinion on 2030. Lastly, for France, the négaWatt association attempted the exercise and estimates that the digital consumed 8.5% of the country's electricity in 2015 2% of which for data centers (or 10 TWh/year).[6] There is however no study "territorializing" worldwide projections in France today.

2- More digital will not solve the ecological and climate crisis

The discourse of data center operators and digital companies raises the specter of an energy and infrastructure surge that these projections partially reflect, and for which it may be feared that they become self-fulfilling prophecies. The 100 billion connected objects projected for 2030 by Cisco have already been revised downward, and doubts have appeared as to consumers' saturation and the belief in unlimited growth, "all things being equal besides." Let us recall, with Jonathan Koomey, a researcher at Stanford University and a world-renowned specialist in data centers, that such exaggerated discourses could, in the past, lead to a harmful infrastructural oversizing.[7] He consequently cites a massive overinvestment in optical fiber in the United States, based on a false figure, repeated without being verified, in the second half of the 1990s. This also echoes the observations of GIMELEC, which stresses the oversizing of many colocation data centers in France, filled on average at 30% but calibrated for constant growth. Lastly, it must be recalled that at this stage, "smart" will not reduce the climate and energy crisis, and in fact, the opposite is true. No study proves that the overall assessment will be in favor of the digital.[8] It could further aggravate the problems that it claims to solve,[9] despite the technical solution discourses.

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[1] Networks, data centers, computer terminals.
[2] Guillaume Pitron, *La guerre des métaux rares, la face cachée du numérique,* Éditions Les Liens qui Libèrent, 2018.
[3] Hugues Ferreboeuf, *Lean ICT*, report, The Shift Project, 2018.
[4] Andrae Anders S. G. and Edler Tomas, "On Global Electricity Usage of Communication Technology: Trends to 2030," *Challenges* 6, 2015, pp. 117-157. In this study, worldwide electricity consumption in 2013 was estimated at 21,000 TWh and projections for 2030 reached 61,000 TWh. The annual production of a nuclear reactor is 7 TWh.

[6] négaWatt, https://decrypterlenergie.org/la-revolution-numerique-fera-t-elle-exploser-nos-consommations-denergie
[7] http://www.koomey.com/post/179556571967
[8] Deloitte Développement Durable, EcoInfo, Futuribles and the CRÉDOC, *Potentiel de contribution du numérique à la réduction des impacts environnementaux : état des lieux et enjeux pour la prospective*, ADEME study, 2016.
[9] Today, the digital sector is increasing its CO_2 emissions by 8% a year (whereas it should reduce them by 5% a year) to remain under the 1.5°C increase in worldwide temperatures) and could emit as much of them as the automobile industry in 20252025. Source: *Lean ICT*, report, The Shift Project.

3- Energy territories destabilized by data centers

Beyond the global projections cited above, the spatial impacts of data centers have been barely documented until this point, all the more so as we can note major concentrations of data centers in certain strategic territories (Plaine Saint-Denis, Silicon Valley, Marseille, etc.), mutating and vulnerable to certain effects of climate change (floods, heatwaves, drought, wildfires, etc.). If we identify polarization zones today, data centers, in their diverse sizes and uses, are present on very many types of territories and question their energy projects each time.
How can territories obtain better benefits from them?

- Reduction and infrastructural redundancy: benefits to be obtained for the territories

Data centers, whatever their type, have doubled infrastructures in case of a breakdown: a second electricity source, batteries and backup generators using diesel oil for the most part. This redundancy requirement could become a shared resource for the host territories, as Portland General Electric (Oregon) is doing with a smart grid connecting 85 customers (including five data centers) having backup generators (121 MW in total). The electricity company can mobilize them in case of a breakdown on its network. In exchange, it manages maintenance and buys fuel for all the generators. Nonetheless, the problems of air pollution linked to the use of fuel-oil generators (the fuel could be replaced by gas or biomass) must not be concealed.

- Big Tech, new energy actors

In the United States, the major digital actors are accelerators of the use of renewable energies, in particular solar and wind. This enables them to ensure the continuous growth of their services, through stable prices and an energy sovereignty asserted by massive investments on their part, as well as intensive negotiations with traditional energy operators, pressured by these rapid and massive demands for power. Facebook and Apple consequently co-invested with Pacific Corp, an energy operator in Oregon and Northern California, to create two 15-MW solar farms each, in the vicinity of their data centers in Prineville (Oregon). Certain digital actors also joined the Renewable Buyers Alliance (RBA) to collectively negotiate renewable energy contracts. If they consequently support the development of renewable energies, they do not question large-scale energy developments. The digital sector in the United States is moreover inserted into a specific geography, where three electricity networks operating almost autonomously (East, West and Texas) with more weaknesses and less reliability than in Europe. This partially explains the partiality of the major digital actors for more local provisioning in renewable energies, a part of whose resource they may partially control. Apple consequently created the Apple Energy subsidiary, accredited by the Federal Energy Regulatory Commission (FERC) and all the digital majors have developed very specialized competencies in the domain. Some of them also wish to take autonomy further with micro-network development projects like Microsoft, in, for example, Wyoming.
None of them however proposes a discourse on the energy and digital sobriety needed to remain under the prospect of an increase in worldwide temperatures of 1.5°C that for the moment nothing permits seriously envisaging.

- Difficult pooling:

The waste heat discharged by data centers comprises a source of energy recoverable for other uses. Their average temperature (40 to 50°C) is not a curb for the most recent urban heating networks, and pump systems can raise temperatures for the oldest networks.
However, very few projects have reached this stage, in France or worldwide. We can cite the BNP Paribas data center in Bailly-Romainvilliers (77), which heats the neighboring nautical center, or that of Céleste in Noisy-Champs, which heats its own offices, while small-scale systems doing high-performance computing for the 3D or video games sector, are paired with residential uses (Qarnot radiators in apartments) or public uses such as Stimergy's digital boilers, which heat part of the water of the swimming pool in Butte-aux-Cailles (Paris, 13th arrondissement) for example. Despite the prospective work of the DRIEE (Regional and Interregional Department for the Environment and Energy), in the preparatory work for the SRCAE (Regional Climate, Air and Energy Plan) in 2010 and the ALEC of Plaine Commune in 2013, heat recovery remains very infrequent. There are two kinds of curbs: first economic. Economic profitability models, project interests and timelines

diverge between data center developers that commit to returns on investments over very short periods (between two and five years) whereas the contractualization for heating networks, forced to make commitments over durations of 25 to 30 years. Next there is a technical curb that limits initiatives. In fact, it is preferable, for an operator, to envisage recovering heat when the data center is first built because intervention and work on an existing installation could disturb its operations, and in their opinion, would often be too costly. The connectable distance and temperature needed must be studied in detail (heating networks in the Île-de-France have temperatures generally between 60° and 110°C, while data centers rather have temperatures of 40°-50°C). To heat new buildings, the relevance of the connection and costs must also be evaluated because, with the RT 2012 standards (and the subsequent energy regulations to come), temperature needs are sometimes not as high. The development of heat recovery remains subject to a political determination that combines urban and energy planning. In Stockholm, a particularly interesting example drew our attention: the Data Center Parks program developed since 2016 that combines energy, digital and real-estate strategy. On land belonging to the city, served by a heating and cooling network from the Exergi municipal company, by fiber from Stokab, another municipal company, and by major and inexpensive electrical power (Ellevio), the city proposes a long-term lease to data center operators (like Multigrid and Interxion) to set up, offering them free cooling in return for their waste heat. The city wishes to eliminate the 10% of fossil fuel remaining in its consumed energy sources, notably by recovering the heat discharged by the servers in the data centers.

- Pressure on electricity systems:

In France, the very strong electrical power needed by data centers is a tricky and relatively opaque subject: Enedis cannot talk about, with the support of precise data, given the obligation of discretion and business confidentiality. Data centers attempt to capture a lot of power to put the brakes on the competition. They generally ask for greater power than the one they will subscribe to in the end, but this will block a certain number of MW for months, while their request moves up the waiting lists. And as described above, several years will often pass before the data center really consumes the power that it subscribed to. There is consequently an unwarranted mobilization of electrical power that could penalize other uses in a territory a mobilization that moreover leads to new investments on transmission and distribution infrastructures, like source substations.

In the United States, we may equally note strong pressure from Big Tech and colocation operators so that the electricity transmission operators invest in new infrastructures whereas governments are promoting "non-wire alternatives" and better management of the demand and development of micro-networks, that is, the contrary. The Prineville case is one illustration: Pacific Corp, Apple and Facebook consequently have demanded that the Bonneville Power Administration finance a new high-voltage line in the heart of Oregon.

On the American market, we can observe a very strong competition situation between the digital actors and the historic electricity actors. GAFAM are increasingly developing their energy autonomy through onsite or nearby production infrastructures. Facebook and Microsoft, for example, are heavily involved in the development of micro-networks following the example of Microsoft's data center park project in Colorado, which will produce 200 MW onsite.

4- The public sector and digital infrastructures, a link to be strengthened

The public sector (government, local administrations, public corporations, universities, hospitals, etc.) have their own storage capacities, and also rely on private cloud and hosting actors. The higher education and research sector, on which this report proposes a focus, illustrates a desire for the rationalization of their data processing and storage installations, while stressing the difficulties encountered in pooling them between public actors, despite the project's needs and relevance, notably due to the decision-makers lack of knowledge on the sector, the complexity of governance of the actors and certain legal curbs.

Whereas the public sector has played a major role in the development of electrical, rail, maritime or hydraulic infrastructures, and that many local administration are municipalizing public service for water (the city of Paris, for example) or have a public actor for gas and electricity (GEG in

Grenoble), the question of the public sector's involvement in ecologically exemplary data centers, territorialized and effectively pooled, can legitimately be raised.

5- Data centers reinforce the urban hierarchies in place, and favor urban sprawl in semi-urban and rural areas

The digital technical system followed the preceding networks in its routes and sitings: fiber runs along urban, road and rail networks, and data centers are being installed nearby.
Far from the idea that the digital would abolish distances and upset the urban hierarchies in place, inversely digital infrastructures reinforce the geographies as they now stand.

- The world's large metropolises like Paris, London, New York and Los Angeles are Internet hubs, and we find in overequipped digital buildings in the very heart of the cities, both data centers and major Internet hubs. Indispensable to certain economic activities for which latency must be the lowest possible, the operate in direct complementarity with their former urban or industrial service zones built in the 19th and 20th centuries: Plaine Commune for Paris, New Jersey for New York, and Santa Clara for San Francisco and Silicon Valley.

- These new digital economic zones are undergoing a growing concentration of data centers because each newcomer improves the connectivity of the whole and their proximity reduces the fiber connection costs between them. This polarization is accompanied by real-estate and increasing environmental pressure for these territories, aggravating their vulnerability notably faced with extreme climate events, today's and those to come.

- Lastly, the most powerful digital actors, Big Tech, are rolling out data centers in rural and semi-urban territories: in Oregon, Iowa, Ireland, Sweden and the Netherlands for example. Faced with weakened local administrations or governments, these actors lay down their conditions in an asymmetrical negotiation that pushes certain territories to over-calibrate energy, hydraulic or road infrastructures to be able to host a few dozen of them, or hundreds of jobs if we include the construction phases, but also to run a harmful tax dumping scheme. This spatial sprawl will moreover run counter to the necessary protection of the soil against artificialization, nonetheless critical to remain under acceptable temperatures in the future.

6- Data centers, a new real-estate program, little architecture

Since the development of data centers in the early 1990s, the industry has shifted from a building transformation phase to a dedicated building construction phase, in series, with however differences according to the types of territories.

- In the large metropolises, it was often the former telephone offices that were transformed, as in New York (former head offices of ITT, AT&T, Western Union, etc.) or the main post offices (Coresite in Los Angeles), but also cast-iron industrial buildings (for the press and garment industry in the Sentier district in Paris, a former cookie factory in New York, a former automobile plant in Courbevoie). A new transformation dynamic could develop in the years to come, as illustrated for example by the partnership between the Qarnot company, known for its digital radiators, and the Casino retail chain that is aiming at transforming part of its commercial assets into a data center.

- In digital economic zones, if the dynamic also began with transformation (Equinix in the EMGP in Aubervilliers; Infomart in a former electronics plant in Hillsboro, near Portland), very quickly, in the 2000s, dedicated buildings were constructed in a serial manner, with as their main concerns the functional and secure nature of the whole. These digital facilities became real-estate investment products and many data center operators are moreover real-estate investment funds (Real Estate Investment Trust [REIT] like Digital Realty and Equinix).

- Unlike stations for the railroad network or production facilities for the electricity networks, architects are given very little latitude on these programs, which remain largely in the "shoebox" format, and no ambition to make them the new signals of the digital society has been displayed. A few exceptions however may be noted: as in France the creations of the Enia agency, specialized in this area; in the United States, it is the data center operator Coresite in Santa Clara, the data centers of companies like Adobe in Hillsboro, designed by Gensler, and the Apple data center in Prineville, which has perpetuated its taste for design in it.

7- <u>The worldwide trends of data centers: growth, interdependence, centralization</u>

The first strong trend is the growth of data centers in the three types of territories identified:

- The edge and the cloud will enrich the development of storage capacities and data processing in the very heart of metropolises.
- The concentration and polarization dynamics will continue in the digital economic zones. The data center cluster is consequently spreading from Santa Clara to San Jose in Silicon Valley, while it is being deployed toward La Courneuve in Plaine Commune…
- American and Chinese Big Tech firms are continuing their development and construction of hyper-scale data centers, preferably in rural and semi-urban territories.

The second trend is the growing interdependence of the data center technical system. IT configurations (edge, the Cloud in particular) are accompanying complementary spatial sitings on territories between rural/semi-urban (very large data centers) and urban territories (colocation and edge relays).

- Cloud companies increasingly need colocation data centers, through their metropolitan location and therefore a low latency level for Internet users, but also their rapid growth capacities.
- The edge computing required for the Internet of Things (IoT) will make micro-data centers relays between "core" data centers and things, increasing operational interdependencies between them.

Data centers will therefore function even more in an interconnected network, and the growth of one will bring about that of the other: we therefore are seeing the consolidation of a digital macro-system, which seems less and less resilient.

The third major trend is centralization. The centralized macro-system dimension is prevailing over the distributed and micro-systemic system that was at the origin of the Internet's history. This trend, already started with the arrival of the Web in the early 1990s, needs in cyber-security, was asserted next with the desires of governmental control over information in a great many countries, to put an end to Net neutrality by the telecom actors, and lastly, by the monopolistic nature of Big Tech (Google, Facebook, Amazon, Alibaba, etc.) that controls the main services of the net and the billions of data of people and companies. Despite a large number of initiatives focused on a distributed Internet and storage systems on a smaller scale and that consume less energy, Internet architecture is being increasingly centralized, intelligence located in clouds and data centers, while computer terminals are more and more kept in check and weak in software as well as in memory. Internet users are consequently becoming very dependent on data centers, their connectivity, without having any hand in them at all.

17 recommendations to improve the trajectory of data centers

The public authorities have only very little power over the data center market and more broadly the development of digital infrastructures. Their role however is central to shift toward a more sober digital, to better incorporate it into our landscapes and territories, to better regulate data centers and guide them toward good energy and environmental practices.
We therefore propose three types of recommendations for France (whose details are presented in the complete report), as well as complementary studies to be conducted.

1- Recommendations: governance and actors

- 1: Create a "territories, energy, digital" exchange forum
- 2: Enrich the ecosystem of the ISPs for the digital and social resilience of the territories
- 3: Launch an invitation for projects for territories of digital and ecological experimentation
- 4: Create a public service for the digital and public data centers

2- Recommendations: urban planning and environment

- 5: Favor to the maximum the transformation of buildings for the installation of data centers
- 6: More architecture and more programmatic hybridization
- 7: Include the data center question in spatial planning documents and territorial strategies
- 8: Anticipate the siting of hyperscale data centers and edge computing
- 9: Measure and limit the environmental impact of the "smart"
- 10: Incorporate the learning and knowledge of digital infrastructures into the development policy of third places and the revitalization of town centers

3- Recommendations: energy

- 11: Sobriety: support it, quantify it and evaluate it
- 12: Reconcile energy planning and urban planning
- 13: Favor heat recovery and accompany it on the regional scale
- 14: Enedis and the waiting line: eliminate over-reservation
- 15: Develop renewable energies, local productions and interconnected micro-networks on data center sites linked to the traditional network and neighboring sites
- 16: Pool dormant energy infrastructures through interconnection
- 17: Promote infrastructural diversity and a less centralized approach

4- Complementary studies to be conducted

We propose continuing research on the following themes:
- Evaluating specific climate risks for digital infrastructures in France;
- Studying the feasibility of an intermediate operator on waste heat recovery from data centers;
- Evaluating the ecological impact of associative, decentralized distributed and peer-to-peer infrastructures;
- Deepening the development potentials of infrastructural mediation in third places in France, as a lever for jobs and local resilience;
- Complementary study on the challenges of urban, energy and territorial integration of hyperscale and micro-data centers (edge);
- Simulating the impact of "smart" projects on the environment: tools to develop for ecological reviews of projects.