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Corbo, S.

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Bologna and its Computing Centers: An Archaeology of Urban Media (1961–2022)

by Stefano Corbo

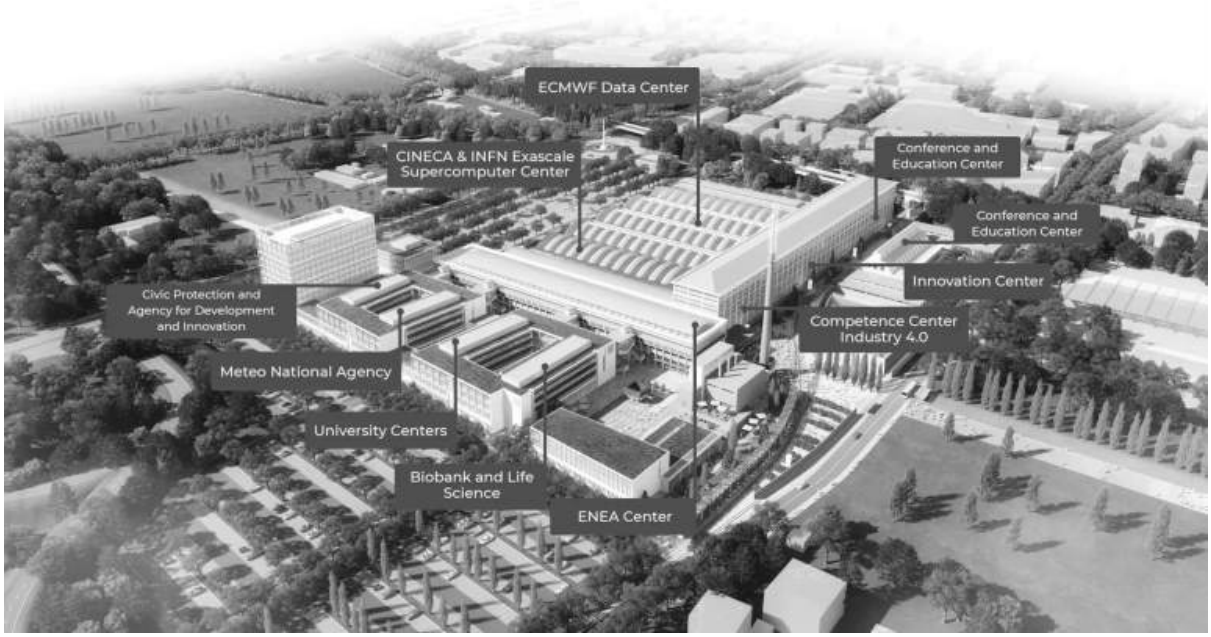
Pier Luigi Nervi, Manifattura Tabacchi, Bologna, 1952. Photo: Marcus Bredt. https://divisare.com/projects/437737-pier-luigi-nervi-marcus-bredt-manifattura-tabacchi

Bologna is one of the main data processing hubs in Europe. Stefano Corbo traces the infrastructural and architectural development of the city's computer centers, arguing that to understand the recent history of the city, we must pay attention to the material history of data.

November 22, 2022. Bologna, Italy. The President of the Italian Republic Sergio Mattarella attends the inauguration ceremony of Leonardo, a supercomputer ranked fourth on the TOP500 list of fastest computers in the world. The supercomputer has more than 5,000 servers that weigh a total of 360,000 kg and more than 156 km of cables; it occupies a room of 32x23x3.80 meters, stacked between two levels of power generators and cooling systems. Partially funded by the European Union, Leonardo will help to mitigate and manage risks due to extreme situations such as earthquakes, tsunamis, volcanic events, etcetera.

Most importantly, the inauguration ceremony of Leonardo takes place at the so-called Tecnopolo – one of the main European hubs for data processing, comprising more than 100,000 m^2 of research facilities and infrastructure for high-performance computing. The Tecnopolo accommodates facilities of both national and European institutions: among them, the data center of the ECMWF (European Centre for

Medium-Range Weather Forecasts), a multi-governmental organization founded in 1975 by 24 countries, as well as the data center of the INFN (Istituto Nazionale di Fisica Nucleare), research facilities of ENEA (Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile), and incubators for companies in the fields of AI and Climatology.



Aerial view of the Tecnopolo, Bologna. Image courtesy of Leonardo CINECA.

Located in a former tobacco factory designed by Pier Luigi Nervi in 1952, and converted to new uses by the Hamburg-based architectural firm gmp Architekten (von Gerkan, Marg and Partners) in 2011, the Tecnopolo plays a paradigmatic role within the Italian context of research. It represents the culmination of a five-decade trajectory which saw Bologna progressively emerge as the Data Capital of Italy – the city which, earlier than other possible competitors such as Rome and Milan, opened the doors of its research centers to advanced computing machines, and where forms of cooperation between the public and private sectors took place. Starting from the early 1960s, in fact, three major moments have shaped the data landscape of Bologna: in 1961, the opening of the Computation Centre at CNEN (Comitato Nazionale per l'Energia Nucleare), in which the first digital mainframe computer was installed – the IBM 704; in 1967, the foundation of CINECA (Consorzio Interuniversitario per il Calcolo Automatico dell'Italia Nord Orientale) – a research center originally based on the collaboration among the Italian Ministry of Education and four different academic institutions, famous for its research projects on molecular dynamics; and, finally, in 2016, the foundation of the above-mentioned Tecnopolo with its Leonardo supercomputer. Today, Bologna is still the city where most of Italy's computing centers and data storage centers are located; in the coming years, however, Bologna's ambition is also to play a leading role within the European constellation of research institutes and, in this sense, the Tecnopolo constitutes a milestone in such a process.

By mapping the presence of buildings, computing machines, and data infrastructure in the city, as well as by analyzing the research conducted in its centers over the decades (first on nuclear energy, then on information technology, and now on machine learning), this article analyses the role of Bologna as Data City between 1961 and 2022. It shows that Bologna gained this significant position in the context of Italy because it was favored by a progressive local political environment, and was supported by dynamic

academic institutions which helped turn the city into a testing ground for new technologies and new processes of modernization.[1]

Map of Bologna's major computing centers. Image courtesy of Stefano Corbo.

Over the decades, a network of computing machines, buildings and research institutes has invaded Bologna's urban fabric. A parallel (media) infrastructure has overlapped with the traditional city, adding another layer to its sedimented history. As Shannon Mattern puts it, "in cities across time and across the globe, both ethereal and resolutely material media have always coexisted."[2] This media infrastructure was constituted by chips, radiant floors, cooling systems, servers and racks that have had and still have a tangible impact on the surroundings: one that is environmental, but also connected to the evolution of the city fabric over the past few decades. In Bologna, in fact, advances in information technology (and in its machinery) have run parallel to the need for new spaces that could physically host computers and servers, and to projects of urban development such as the Tecnopolo.

This article analyses those spaces and projects, scattered over the city fabric, to illustrate how Bologna's relationship with data, as Shannon Mattern explains, is at the same time "immaterial and material, wireless and wired… both ether and ore, code and clay."[3] By investigating the entanglement which occurred in Bologna between technology, space, and power structures, this article indirectly traces the trajectory of Italy's recent economic and political history: from the post-war reconstruction, symbolized in the country's efforts to develop research on nuclear power, to the 1980s era of diverting national interests from the nuclear to other sectors, until, very recently, the implementation of projects and

initiatives in collaboration with other countries within the framework of the European Union. What follows is a reading of this and other histories.

From CNEN to ENEA

Bologna's relationship with computing centers began in the mid 1950s at the city university's Faculty of Engineering. Here, the Municipality and the Ministry of Education invested 100 million Italian lire to purchase an IBM 650 computer,[4] whose first version had been originally launched in 1954. Very soon, however, new research needs required the purchase of a more advanced machine – the IBM 1620. This switch allowed the University of Bologna not only to carry out more complex research projects, but also to compete with other Italian cities such as Pisa, which, in the same years, had already taken the first steps in the field of computing. During the 1950s and 1960s, the University of Pisa had in fact founded the CNUCE (Centro Nazionale Universitario di Calcolo Elettronico) and had been the first university to collaborate with the Italian company Olivetti on their pioneering computer, ELEA (Elaboratore Elettronico Aritmetico). In response to Pisa's dynamism, two research institutes were founded in Bologna: the CNEN (Comitato Nazionale per l'Energia Nucleare) and the CINECA (Consorzio Interuniversitario per il Calcolo Automatico dell' Italia del Nord Orientale). Gradually, most of the research projects originally undertaken by the University of Bologna were transferred to these institutes, where more powerful machines had been installed.

The CNEN was established in 1960 by an initiative of the Italian Parliament, which aimed to foster research into the design and implementation of nuclear plants. The goals of the Centre were: a) to develop a series of research projects in the field of nuclear codes; b) to conduct research in the field of nuclear reactor physics; and c) to design and experiment with the RB-1 (Reattore Bologna Uno), a nuclear research reactor which became operational in 1962.

CNEN's first headquarters were located just outside of Bologna's medieval walls, in Porta Mazzini, on the border between the historic city and its most recent expansion. Porta Mazzini, also known as Porta Maggiore, was one of the main gates within the defensive walls of the city. Built out of brick during the thirteenth century, the gate underwent several modifications over the centuries, including a total reconstruction in 1770. Here, besides the remains of these ancient defensive walls, the CNEN occupied two anonymous buildings, whose layout and configuration were very distant from the typical image one might have of research centers. From outside, the CNEN appeared, in fact, as an ensemble of post-war Italian residential buildings: between five and six stories high, the buildings had a concrete structure with brick infills in the façade.

View of the two buildings hosting the CNEN, 1961. Image courtesy of Notiziario CNEN.

Despite the unusual design for a nuclear energy research center, the interiors of these two buildings were massively transformed to be able to accommodate advanced computing machines such as the IBM 704 Data Processing System, the first scientific calculator purchased by the CNEN. The IBM 704 was the first mass-produced computer with hardware for floating-point arithmetic; it allowed complex math, and made it possible to conduct research on multiple levels, from physics to music, to game theory. The 704 required a huge amount of space to be installed and to run properly: it occupied the whole basement of one of the two buildings at CNEN – approximately 500 m^2.[5] In addition, a raised floor was necessary to host meters and meters of cables, which transmitted signals from one unit of the 704 to another.

An IBM-704 computer in 1957. Image courtesy of NASA https://en.wikipedia.org/wiki/IBM_704#/media/File:IBM_Electronic_Data_Processing_Machine_-_GPN-2000-001881.jpg

At the end of the 1960s, a new site for the CNEN headquarters was chosen outside of the city center, in the area of Arcoveggio, where more existing buildings were available. In 1982, the CNEN became ENEA (Ente per Le Nuove Tecnologie e l'Ambiente), whose mission was to promote research in the field of alternative energy, new technologies and the environment. The ENEA is today a national institute with different branches across the national territory.

While the ENEA initially inherited the use of IBM models (IBM 360, 370, 390 and then 9000), progressively new computing infrastructures were installed later. At the beginning of the 2000s, the ENEA was equipped with different systems, until the arrival of the supercomputer CRESCO6. During the COVID-19 pandemic, CRESCO6 was used to perform thousands of molecular dynamics (Molecular Dynamics, MD) and computational fluid dynamics (Computational Fluid Dynamics, CFD) simulations, aimed both at identifying molecules for new drugs active against the virus and at studying its propagation among people in closed environments.[6] Today, the ENEA collaborates with other national research institutes in the field of biotechnologies, climatic simulations, and aerospace.

The ENEA branch in Bologna is still located in the same area where the CNEN was housed. Here, it is spread across two different clusters, for a total of five buildings. The ENEA complex includes offices, laboratories, a library, an infirmary, and a canteen, but also large areas for experimental research. Like CNEN's initial headquarters, none of those buildings was originally designed to host research facilities but they were all progressively adapted to new uses at different stages.

Satellite view of ENEA's Headquarters, Bologna. Image courtesy of Google Maps.

The ENEA's complex integrates other lab facilities, such as the so-called *Centro di Montecuccolino*, which was originally opened in the 1960s by the CNEN and the Faculty of Nuclear Engineering at the University of Bologna to conduct research on experimental physics. At this site, three nuclear reactors were initially installed. While two of the reactors concluded their activity of research at the beginning of the 1980s, the last reactor was closed after the 1987 national referendum on nuclear energy.[7] The buildings that originally hosted the reactors were reconverted to new uses. Today the Montecuccolino Centre consists of three buildings, connected through skybridges, accommodating offices from the University of Bologna, labs, and a library. The building hosting the third reactor is now to be dismantled for good.

The brief history of CNEN first, and of ENEA later, not only describes the various strategic orientations put in place by the Italian political system to support research and innovation. Most importantly, the transition from CNEN to ENEA represents a first decisive step in the expansion of Bologna's media infrastructure: progressively, a jumble of tangible and intangible spaces grew out of the historic city center and colonized Bologna's suburban as well as rural areas. For the first time, this media infrastructure went beyond the boundaries of the traditional city to acquire an expanded and potentially limitless dimension.

CINECA and the birth of the supercomputer

Besides the CNEN, in 1967 Bologna saw the creation of a new research center: the CINECA. The CINECA was originally founded inside the Italian academic world to equip the country with advanced computing machines whose costs were too high to be afforded by only one university. Four academic institutions and the Ministry of Education signed an agreement of collaboration, aimed at promoting research in the field of information technology: the universities of Bologna, Florence, Venice, and Padua were initially involved in this ambitious project, which today encompasses 69 Italian universities and 27 public institutions.

The CINECA was conceived not only as a research institute, but also as a platform to facilitate public and private partnerships,[8] offering support through supercomputing and innovative computing systems. Since its constitution, the CINECA has been the most important computing center in Italy; its activity has been always characterized by the use of advanced machines and by a progressive expansion within the national territory – the CINECA has today other branches in Milan, Rome, Chieti, and Naples.

Everything started in 1969, when the CINECA opened its doors in Casalecchio di Reno, six kilometers from Bologna. The choice of Casalecchio was mainly determined by the need to pick a location which could strategically serve the interests of the researchers who were supposed to work there – a site close to the highway, easy to access, and able to connect Bologna to other cities of Italy.[9]

Satellite view of CINECA's Headquarters, Casalecchio di Reno. Image courtesy of Google Maps.

Initially, the CINECA's headquarters was composed of one building with two apartments, and a warehouse accommodating water bottles. In the same year, thanks to the collaboration among the four universities mentioned above, the first supercomputer arrived in Casalecchio. It was the CDC 6600 (Control Data Corporation), rented in 1968 for a duration of five years. Similar to the aforementioned IBM 704, the CDC 6600 was not only the most powerful computing machine ever produced; it was also extremely heavy and expensive – it costed more than 2 billion Italian lire. The life of CDC 6600 was not that long, as it was replaced in 1974 by an updated model – the CDC Cyber 70/76. One of only 40 ever produced, this machine arrived at the CINECA in 1975. In the same years, CINECA's process of expansion continued and involved the acquisition of the two buildings originally leased in 1969, as well as the construction of new structures. In total, more than 1000 m^2 for research facilities were added.

Control room of the CDC 6600 – CINECA, Bologna. Image courtesy of CINECA.

Such a process also implied the need for new computing machines: 1985 was the year when the CDC Cyber 70/76 was replaced by the Cray X-MP/12, for an amount of more than 12 billion Italian lire. As recalled by the former director of CINECA, Marco Lanzarini, the installation of this supercomputer required extraordinary operations of logistics and site planning. The Cray X-MP/12 landed in two containers at the Milan Malpensa Airport and was transported to Bologna by trucks. Also, a new wing of the CINECA headquarters needed to be built, with a total surface of 450 m^2: "the building was a sort of bunker, with thick external walls, reinforced window frames, and a floating floor.'[10] Floating floors allowed the passing of cables, and in addition were reinforced with a concrete substructure that could hold the weight of the Cray X-MP/12. Later, the Cray X-MP/12 was replaced by its updated version: the X-MP/48, capable of supporting studies on theoretical physics, molecular dynamics, and mechanical engineering. At the same time, the presence of this supercomputer also allowed the CINECA to collaborate with big public and private companies such as Finmeccanica, FIAT, Ansaldo, and Ferrari, which needed supercomputers for their own projects of research and development. In this respect, the CINECA was an anomalous public institution: founded to serve national interests of research and innovation, it also progressively embraced those private enterprises willing to develop ideas or projects.

Control room of the CDC 6600 – CINECA, Bologna. Image courtesy of CINECA.

At its foundation, the CINECA only counted 20 employees, but its role within the national boundaries has been progressively increasing; in 1998 it counted 90 employees, rising to 170 by 2000. Today, it employs more than 500. Similarly, while in 1969 the CINECA consisted of only one building and one warehouse, today its headquarters stretch over an area of 17,000 m^2 across a total of five buildings. Furthermore, in Bologna, Rome, Milan, and Naples, all CINECA's buildings follow specific design guidelines in terms of energy efficiency, circularity, and water management. Its interiors are characterized by recycled materials and timber elements; climate control is achieved through systems of shading and passive techniques.

In 2016, the CINECA introduced its flagship supercomputer: MARCONI, a high-performance computing system that in November 2019 was ranked 19th in the Top500.[11] One of its partitions is currently used by the European consortium EUROfusion, which investigates how to develop fusion energy. Thanks to MARCONI, the CINECA today offers consultancy in several fields such as medicine, meteorology, seismology, chemistry and others. CINECA's tasks also include data mining, data warehousing, data management, as well as experimentation in quantum computing and virtual reality. CINECA's growth has represented a further step – a moment of consolidation – in the definition of Bologna as Data Capital of Italy. By establishing its presence in other Italian cities, the CINECA has disseminated its activities across the entire national territory and has created a broader media infrastructure that connects Bologna to the rest of Italy; yet, now more than ever, the name of CINECA is associated specifically with Bologna and its spaces.

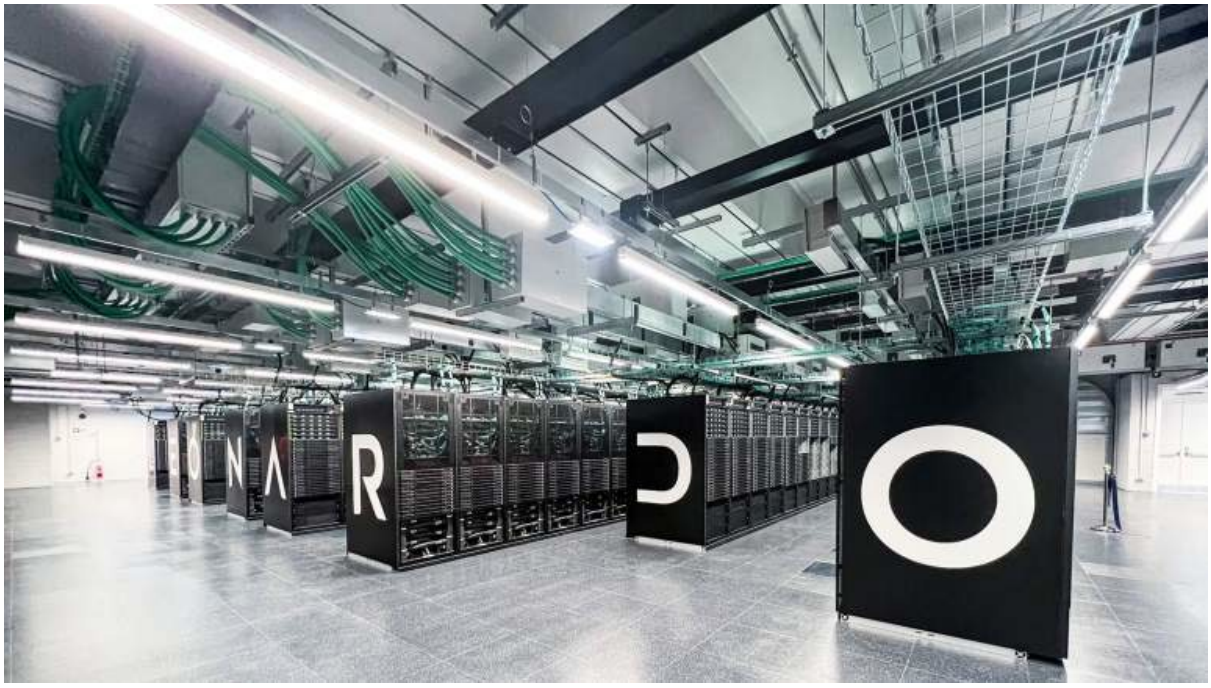
The Tecnopolo and the Data Valley

In 2018, in fact, with the support of the Emilia Romagna region, the CINECA opened a data center in the Tecnopolo, which currently hosts and manages Leonardo, the petascale supercomputer funded by the European Union (at a cost of €120 million) and by the Italian Ministry of Education, University and Research.[12]

The CINECA, however, is not the only research center to have moved part of its facilities to the Tecnopolo. The Tecnopolo hosts other national and European research centers such as the ENEA, the INFN, and the multi-governmental ECMWF, all of which occupy the spaces of the former Tobacco Factory (*Manifattura Tabacchi*), which originally stretched over an area of 13 hectares, in a portion of the city characterized by military, industrial and railway structures. The general layout of the factory, as per Pier Luigi Nervi's project, has been almost entirely preserved, due to the significance of its architecture. In the factory, in fact, Pier Luigi Nervi could continue his experimentation on the plastic qualities of concrete by employing double-ribbed ceilings and coffered vaults. Nervi conceived the whole project as a combination of different elements: a first part, completed in 1952, which was a 210 meter-long building consisting of five levels; a second part (1954), consisting of five warehouses, each 117 meters long, with concrete barrel vaults, similar to his project in Vatican City – The Paul VI hall (1964); and, finally, a salt warehouse built in the form of a paraboloid. The complex was then completed by a power plant and an office area, now demolished. When fully operational, the factory could house more than 1,000 workers.

After years of abandonment, due to the withdrawal of the Italian State from the tobacco market, the structure was acquired by the Emilia Romagna region in 2007. In 2011, an international competition for the redevelopment of the area was won by gmp Architekten (von Gerkan, Marg and Partner). The masterplan, which covered an area of 120,000 m^2, concerned not only the preservation of Nervi's original structures, but also the addition of new buildings able to accommodate research laboratories, teaching facilities, offices, and multipurpose rooms, whose major objective was to " to overcome the barriers separating the complex from the city, creating a new and strong integration with the urban fabric, both in terms of the adjacent neighborhoods and the relationship with the historic center and, on a larger scale, with its territory, becoming an international hub for the digital economy, big data, supercomputing, and climate change."[13]

Apart from hosting national and European institutes, the Tecnopolo promotes itself with the presence of Leonardo, rated as the second most powerful supercomputer in Europe, and sixth position in the global rankings,[14] whose technology will allow to perform tasks related to data analytics, machine learning and artificial intelligence.



View of Leonardo's supercomputer. Image courtesy of Leonardo CINECA.

The advanced character of this supercomputer is directly proportional to the number of spaces it needs in order to perform properly: the structure that hosts Leonardo, in fact, develops across three different levels, to accommodate all different forms of infrastructures: in the basement, are four independent tunnels that serve the cooling system; the ground floor hosts the so-called white spaces – the space which includes racks, servers, storage systems and electrical distribution; and on the first floor, four power stations have been installed. Leonardo's white space is characterized by radiant floors, which allow the passage of cooling pipes.

The room in which the supercomputer is located is obstacle-free, made from reinforced concrete, and designed specifically to resist seismic events. At the same time, Leonardo's structure has also been designed to prevent the risk of fire; in such an event, the room hosting Leonardo is able to prevent the fire from spreading to other parts of the building for around 240 minutes.[15] Despite the building hosting Leonardo complies with the recent LEED regulations (Leadership in Energy and Environmental Design), the material impact of data in terms of energy consumption and usage of water is, generally speaking, dramatic. According to a Greenpeace report on cloud computing and climate change, "the electricity consumed by cloud computing globally increased from 632 billion kilowatt-hours in 2007 to 1,963 billion kilowatt-hours in 2020. When imagined as an emergent nation-state, the Cloud would be today the fifth large consumer of electricity, ahead of India, Canada, France, Brazil, and the United Kingdom."[16] At the Tecnopolo, server racks are cooled with warm water: the water enters the supercomputer cooling circuits at 37° C and exits at 47° C, heated by the CPUs engaged at the maximum possible power in the calculations and processing, to be sent out to the adiabatic disposers, called drycoolers, which bring it back to a temperature of 37° C. The classic refrigeration cycle is therefore not used, as in many other data centers, but only heat exchangers, composed of huge fans, to cool the water, and which exploit a natural adiabatic process.[17]

This paraphernalia of pipes, fans, and generators not only provides an explanation for why data centers are designed and organized in a certain way; most importantly, it also casts light on the massive environmental impact of data centers. In his book *Tubes,* the author Andrew Blum writes about his meeting with a Facebook data center manager who speaks of data as follows: "Data need air. This has

nothing to do with clouds. It has everything to do with being cold."[18] If in 2022, electricity usage by data centers represented two percent of all global electricity usage, this number is set to double by 2026 because of power-intensive workloads such as AI and cryptocurrency mining.[19] With respect to this tendency, CINECA's data center in Bologna doesn't represent an exception, as plans have been made to add 2,600 m² of computing room space and 900 m^2 of ancillary spaces in the coming five years.

Multiple conclusions can be drawn from reading about the Tecnopolo's current configuration and its future. First, the goal of turning the Tecnopolo into a European hub for data processing is about to become a reality, thanks to its ability to attract transnational institutions. In this respect, constant investments in supercomputing have paid off: Bologna and the wider Emilia-Romagna region today contain over 80 percent of Italy's total computing capacity and there are plans to further expand its status as a European Data Valley in which to conduct advanced studies on meteorology and climate change using AI and Big Data.[20] Second, the Tecnopolo is not only the paradigmatic representation of the efforts made by Bologna over the decades to play a leading role in data infrastructure, but also an expression of the perverse connection between data technology, space and power dynamics that characterizes its recent urban history. What emerges, in fact, out of this 60-year journey through machines and computing centers is a reading of Bologna's fabric that expands, shrinks, reconverts, or dismiss its spaces depending on the evolution of data technology. If, at the end of 1960s research institutes abandoned the city center in search of larger spaces and more accessible facilities, then starting from the 2000s abandoned industrial areas within the city fabric became attractive again, because they could easily accommodate complex data infrastructure and other research facilities. In other words, after detecting the scattered presence of research spaces, laboratories, and data centers in Bologna's territory, one realizes that any history of data is a materialist history that acknowledges physicality, environmental impact, and urban transformation. Bologna's data history is, therefore, the story of relations between the tangible and the intangible, the local and the global, the city and its architectures.

Notes

↑1 Starting from the post-war years, Bologna, along with other minor cities in the Emilia Romagna region, has been uninterruptedly governed by left-wing parties: the Italian Communist Party first, the Democratic Party of the Left and the Democrats of the Left later. More specifically, between 1945 and 1999 Bologna only had left-wing mayors.

↑2 Shannon Mattern, *Code + Clay. Data + Dirt. Five thousand Years of Urban Media* (Minneapolis: University of Minnesota Press, 2017), xxix.

↑3 Mattern, *Code + Clay*, xl.

↑4 Anna Ciampolini, Maurelio Boari, and Giorgio Casadei, "Esordio e Sviluppo dell'Informatica nella Scuola di Ingegneria dell'Università di Bologna," accessed May 15, 2024, https://www.aicanet.it/documents/10776/3178360/Ingegneria+Bologna.pdf/412c8aa1-544d-43f3-bc87-4d56887ae41f

↑5 Ezio Clementel, "Il Centro di Calcolo di Bologna," *Notiziario CNEN*, vol.2, (1967): 32.

↑**6** Francesco Iannone, "ENEA CRESCO in the fight against Covid-19," accessed May 15, 2024, https://hdl.handle.net/20.500.12079/63410

↑**7** On November 8, 1987, Italian citizens participated in five national referendums. Three of the five referendums concerned nuclear energy. Italians voted in favour of abolishing rewards for municipalities in whose territories nuclear plants were to be built; abolishing the statutes by which the Committee for Economic Planning could decide about the location of nuclear plants; and, finally, abolishing ENEL – the once State-run provider of gas and electricity – to sign international agreements to build nuclear plants. As a response to Italian voters, in 1988 the Italian Government announced the progressive dismissal of the existing nuclear plants.

↑**8** Marco Lanzarini, *Al CINECA. 50 anni da Protagonisti nell'Informatica Italiana* (Bologna: Pendragon, 2017), 19.

↑**9** Lanzarini, *Al CINECA*, 48.

↑**10** Lanzarini. *Al CINECA*, 118.

↑**11** "High-Performance Computing," CINECA, accessed May 15, 2024, https://www.cineca.it/en/hpc

↑**12** "Ricerca: la commissaria UE Gabriel e il Ministro Messa all'hub dei big data del tecnopolo di Bologna," Ministero dell'Università e della Ricerca, accessed May 15, 2024, https://www.mur.gov.it/it/news/mercoledi-23022022/ricerca-la-commissaria-ue-gabriel-e-il-ministro-messa-allhub-dei-big-data

↑**13** "An Industrial Monument," Buro Milan, accessed May 15, 2024, https://buromilan.com/en/project-2/technopole-former-tobacco-factory/

↑**14** "Top 500 List," Leonardo CINECA, accessed May 15, 2024, https://leonardo-supercomputer.cineca.eu/top500-list-nov23/

↑**15** "Inside Leonardo's White Space."

↑**16** Benjamin H. Bratton, *The Stack. On Software and Sovereignty* (Cambridge, MA: MIT Press 2015), 93.

↑**17** "Technopole," Leonardo CINECA, accessed May 15, 2024, https://leonardo-supercomputer.cineca.eu/technopole/

↑**18** Andre Blum, *Tubes. Behind the Scenes at the Internet* (London: Penguin Books, 2012), 239.

↑**19** "Data Centres and Data Transmission Networks," International Energy Agency (IEA), accessed May 15, 2024, https://www.iea.org/energy-system/buildings/data-centres-and-data-transmission-networks

↑**20** "Tecnopolo Manifattura," Tecnopoli Emilia Romagna, accessed May 15, 2024, https://www.tecnopoli.emilia-romagna.it/tecnopoli/tecnopolo-manifattura-data-valley-hub

Stefano Corbo is an architect and educator at TU Delft – Chair of Public Building – where he serves as Coordinator of the Master's program. He holds a Ph.D and an M.Arch. II in Advanced Architectural Design from UPM ETSAM Madrid. Before joining TU Delft, he taught at several academic institutions in the United States, Europe, the Middle East, and China. Corbo has contributed to several international journals and has published four books: *EXTERIORLESS. Form, Space, and Urbanities of Neoliberalism* (Routledge, 2023), *From Formalism to Weak Form: The Architecture and Philosophy of Peter Eisenman* (Ashgate/Routledge, 2015), *Interior Landscapes: A Visual Atlas* (Images, 2016), and *Notes from the Underworld* (Schiffer, 2019). In 2012 Corbo founded his own office, SCSTUDIO, a multidisciplinary network practicing public architecture. Corbo's research trajectory focuses on the comprehension of spatial and aesthetic conditions that characterize late-capitalist architectural production and that manifest in a diverse constellation of types, typologies and hyperobjects.