MAP REAL ESTATE MARKET INSIGHT

Frankfurt, December 2023

UNVEILING DATA CENTERS: A RESILIENT REAL ESTATE ASSET CLASS – CURRENT TRENDS (PART II OF II)

Introduction

In the second part of our two-part Market Insight series on data centers, we focus on one of the biggest challenges for the future data center market: Compliance with ESG requirements. The growing importance of ESG for stakeholder action will change the industry and is already doing so. In Germany in particular, this is also taking place against the backdrop of high electricity prices, which are likely to continue to rise in the future. This was also made clear at the Data Center Strategy Summit 2023.[1] All components of ESG are having an impact. However, we will not discuss areas S and G (the latter was the subject of Dr. Swantje Westpfahl's presentation) in detail here. Due to the high energy consumption of data centers, E in ESG is particularly important. In this Market Insight, we will highlight the specific challenges that arise from this. We will also present government regulations affecting the market and their consequences, such as the recently passed Energy Efficiency Act ("Energieeffizienzgesetz"). We will show how these developments are fueling innovation in the sector and what solutions are emerging.

The following section begins with a brief summary of the key findings of the first part of our series on data centers. We then outline how the consideration of ESG objectives is already influencing market players today. We then present the new German Energy Efficiency Act, which will have a major impact on the market. The sector is already responding to the various challenges with a large number of innovations. In the final part of this Market Insight, we present some of these innovations which demonstrate the resilience of the market.

Summary of the findings of part I of this Market Insight

Global data traffic is growing continuously. From 2010-2022, the volume of data/information created, captured, copied and consumed worldwide increased almost 50-fold. This is due to a number of ongoing developments and trends that will ensure further growth in the future. These include the continuous increase in the number of internet and mobile phone users, the rapid growth of services such as video streaming and social media, the growing spread of the →Internet of Things[2], →cloud computing and →artificial intelligence, which requires fast data traffic in addition to high computing power.

Parallel to data traffic, the necessary infrastructure has also grown: the number of servers installed in data centers worldwide rose by 45% between 2015 and 2022 to a total of around 86 million. The largest location for data centers worldwide is the North Virginia region in the USA, but Frankfurt and London are also among the top 5 in CBRE's global location ranking. Recently, capacities have been increasingly distributed among the large →hyperscaler data

[1] The Data Center Strategy Summit 2023 is an industry get-together which was organized by the Vogel IT-Akademie in Bad Homburg in October 2023.

[2] This and other terms marked with "→" are explained in the glossary in the appendix to this Market Insight.

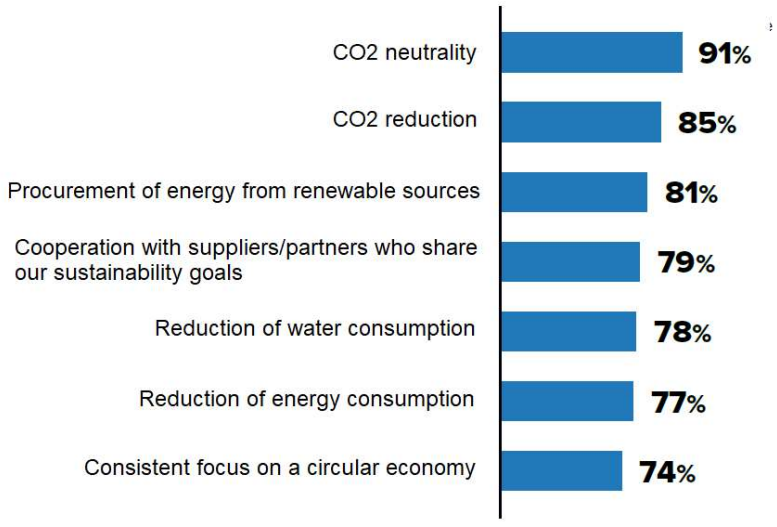
centers, a trend that is likely to continue in the future, also due to the boom in cloud computing and AI; hyperscaler capacities are expected to double in the next five years.

The German market for data centers will also continue to grow. Here, too, cloud computing and the associated trend towards larger units are gaining in importance. As the location of the world's largest Internet hub →DE-CIX, Frankfurt plays a pioneering role. However, developments such as the already high energy prices and their forecast for the future make the outlook for Germany as a data center location somewhat more uncertain than for the major locations in the rest of the world. When asked about the most important qualities of Germany as a location, experts primarily point to the high energy costs as a detrimental factor, while the reliability of the energy supply and legal certainty in Germany are seen as particularly advantageous (see Figure 9 in Part I).

The importance of ESG for the data center market

In the data center market, investors, developers and operators have long taken ESG criteria into account when aligning their strategies. Figure 1 shows the results of a cross-industry market survey of 150 decision-makers with more than 500 employees conducted by IDC, which examined the plans, challenges and success factors of German companies when modernizing data centers and IT infrastructure. Almost all respondents (91%) state that they are actively pursuing or plan to pursue the goal of climate neutrality for their data centers. The reduction of CO_2 emissions is also a very high priority (85%). A lowering of water consumption ranks at the bottom of the chart but is still being pursued by almost 80%. A reduction in energy consumption will also be a common goal in view of the high energy prices, although it is targeted less frequently in comparison.

Figure 1: IDC Survey: „Which of the following sustainability goals for data centers are you actively pursuing or are you planning to pursue?“



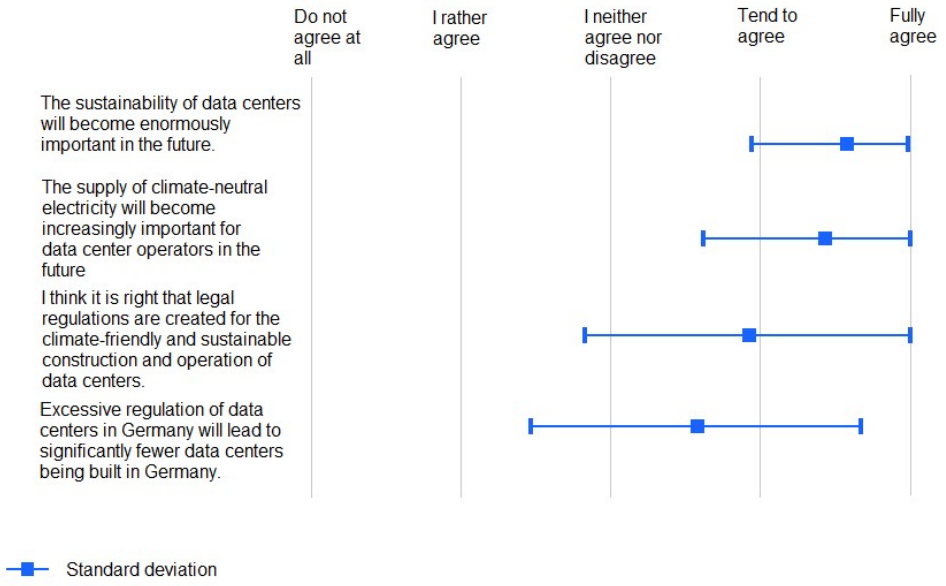
Source: IDC, 2022: Data Center im Umbruch. Deutschland 2022, IDC Infografik.

Another survey commissioned by the industry association →Bitkom also asked about attitudes towards sustainability goals (see Figure 2). The experts surveyed here also rate the importance of sustainability for data centers as very high. They expect the topic to become even more important in the future. Efforts to achieve a climate-neutral electricity supply are also seen quite unanimously as an issue for the coming years. When it comes to the

acceptance of government regulations to achieve environmental goals, approval is lower and opinions are somewhat more divided. The danger that overregulation will damage the location is definitely seen.

In view of the increasing importance of sustainability and social responsibility, ESG principles form a good basis for the search for a sustainability strategy. At the Data Center Summit 2023, Ulrike Stroh pointed out the specific IT-related activities addressed in the EU taxonomy (among others: data processing, hosting and related activities, programming and broadcasting activities).[3] However, according to a study of 100 IT decision-makers conducted by IT company Pure Storage, there is great skepticism in the industry as to whether ESG targets can actually be achieved in the desired form. 88% of those surveyed stated that the future significant increase in the use of AI systems in particular will make it difficult to meet the targets because their resource requirements are very high.[4]

Figure 2: Importance of Sustainability for Data Centers



Source: Bitkom, 2023: Rechenzentren in Deutschland. Aktuelle Marktentwicklungen – Update 2023; online survey of experts by Borderstep Institute in March/April 2023; n=54

In addition to sustainability, social responsibility also plays a major role in ESG, as we explained in one of our previous Market Insights, which highlighted the importance of the S in ESG for the real estate sector. Governance (corporate management) also has a significant influence. As part of ESG-compliant governance, companies and their decision-makers must ensure that they act in a comprehensible and responsible manner. This includes transparent reporting on the company's sustainability performance as well as the involvement of stakeholders in all ESG-relevant decision-making processes. In this Insight, however, we focus primarily on the E, i.e. energy consumption and CO_2 emissions of data centers, and present innovative approaches that contribute to the reduction of both. In the next section, we will first introduce another energy related regulation that has recently come into force and will also have a major impact on the data center industry.

[3] Stroh, U., 2023: Sustainability as a Management Task – How good ESG Management ensures long-term economic success, Data Center Strategy Summit, Frankfurt 19.10.2023.
[4] N.N., 2023: Einführung von KI erschwert das Erreichen der ESG-Ziele. https://www.elektrotechnik.vogel.de/ki-einsatz-unternehmen-herausforderungen-loesungen-a-db9217b5bcc007799d79693b50ad5bf0/

Energy Efficiency Law in Germany

The Energy Efficiency Law ("Energieeffizienzgesetz", EnEfG), which was approved by the Federal Council on October 20, 2023, aims to improve energy use in industry and the public sector.[5] It affects data centers with more than 1 megawatt (MW) for private companies or 300 kW for the public sector. Section 4 (paragraphs 11 to 15) of the Act, which deals with data centers, has been the subject of particular concern in the industry. The main issue were the provisions on waste heat recovery in section 11. Following discussions with IT and data center associations, this section was revised and weakened several times.

Paragraph 11 contains the requirements that data centers must meet on the path to climate neutrality.[6] There is a distinction between data centers commissioned before 1.7.2026 and those that go into operation after this date. The former must have a →Power Usage Effectiveness[7] (PUE) of 1.5 or better from July 1, 2027 and a PUE of 1.3 or better from July 1, 2030. Data centers that go into operation later need a PUE of 1.2 or better. There are differentiated requirements for the reuse of waste heat. These only apply to data centers that go into operation from 1.7.2026. The minimum rate here (for data centers with commissioning from 1.7.2026) is 10 percent. These requirements increase by five percent per year of later commissioning. The maximum is 20 percent for data centers that go into operation from 1.7.2028. However, some exceptions to the first draft versions of the law are important: The most weighty one concerns the case of a lack of recipients for waste heat and exempts from the reuse obligations. Another important paragraph of section 11 concerns the power supply: Half of data centers must be powered by renewable electricity from 1.1.2024 and all of them from 1.1.2027.

It is obvious that the significance of this law is very high for the industry. It will have an impact on Germany's competitiveness as a location for data centers. Within the EU, however, the repercussions might be smaller because it is essentially an implementation of an EU directive. From an investor's point of view, the effect that regularly occurs when regulations for new buildings are tightened should not be overlooked: older properties, in the best case recently completed projects that fall under the existing building guarantee, gain in value.

The requirement for a renewable power supply concerns an area over which the data center operators have little direct influence, as the required electricity is provided by the local supplier. If the latter does not achieve the required proportion of renewable generation, this can only be increased by purchasing so-called green electricity certificates. These are guarantees of origin that companies can acquire independently of physical electricity contracts. At the Data Center Summit 2023, Staffan Revemann pointed out that the certificates, which are generally purchased from abroad, do not automatically mean that German power plants are operated using renewable energy. [8] Other objections relate to the often non-existent additionality of the underlying capacities. This means that the buyers might fund existing renewable energy sources which were already operational and generating clean energy irrespective of the certificate purchase.

[5] Cf. Bundesministerium für Justiz, 2023: Gesetz zur Steigerung der Energieeffizienz in Deutschland. https://www.gesetze-im-internet.de/enefg/BJNR1350B0023.html

[6] Cf. ibid.

[7] Power usage effectiveness is a metric used to assess the energy efficiency of a data center. It is calculated by dividing the total energy consumption of a data center by the energy consumed by the IT equipment.

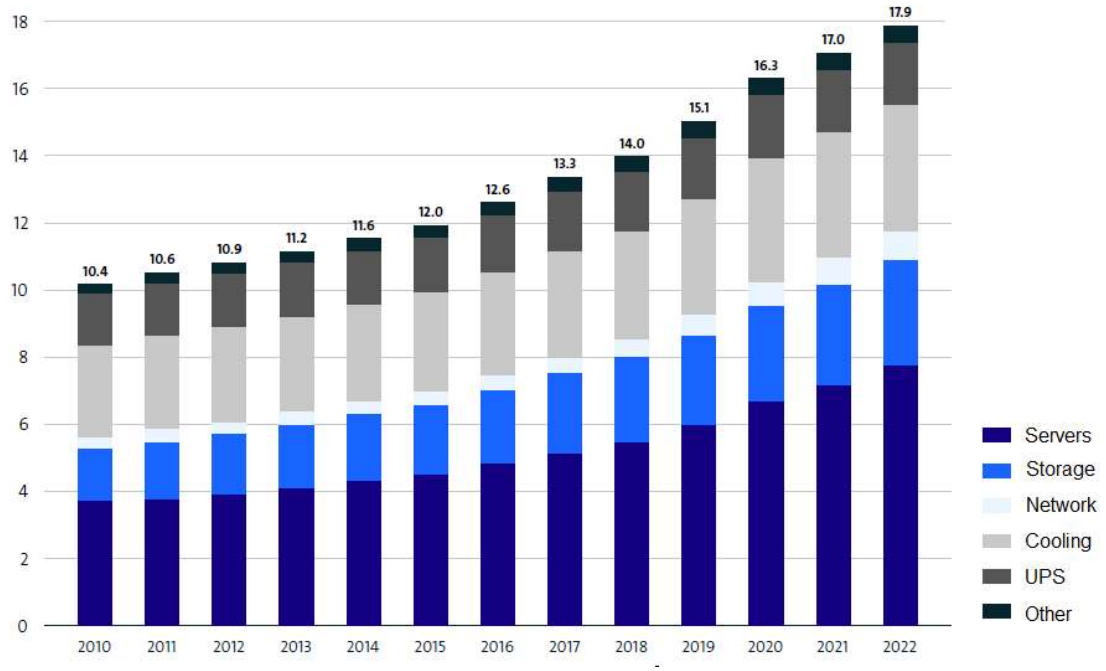
[8] Revemann, S., 2023: Sind unsere energiepolitischen Ziele mit einem starken Ausbau unserer digitalen Infrastrukturen vereinbar und erreichbar?, presentation held on the Data Center Summit 2023, Bad Homburg.

Innovative approaches to lowering energy consumption and reducing the CO_2 footprint

In summary, it can be concluded from the above that ESG criteria and regulations such as the Energy Efficiency Act and, above all, the high energy prices in Germany represent a challenge for data center operators in Germany. Nevertheless, the sector is resilient and still has good growth prospects, which is also due to its innovative strength. In the following, we present selected examples of projects and initiatives.

Figure 3 shows the sharp rise in energy consumption in data centers. This is not surprising given the growth of the sector in the past, as we highlighted above as a result of the last Market Insight. On the other hand, the distribution of energy consumption by source is also interesting. Servers and storage consume more than half of the energy required by data centers in Germany. The next largest consumer is cooling, which accounts for around a fifth. This distribution shows the areas in which innovative measures to reduce energy consumption are particularly worthwhile.

Figure 3: Energy Consumption of Data Centers in Germany 2010-2022 – in billon kWh per year



Source: Bitkom, 2023: Rechenzentren in Deutschland. Aktuelle Marktentwicklungen – Update 2023

Reuse of waste heat

The high proportion of electricity required for cooling in data centers suggests using the heat generated in the process, e.g. feeding it into the local district heating network or for a neighbouring swimming pool or the greenhouses of a horticultural business.[9] Both are consumers that can also be supplied with lower circulation temperatures. Use in the district

[9] A greenhouse is heated by the waste heat from a data center at the University of Göttingen. Cf. Yahyapoor, R., 2023: Strategien für ein modernes Datacenter – Von der Cloud zu KI und Supercomputing, presentation held on the Data Center Summit 2023, Bad Homburg.

heating network is often hindered by the fact that the temperature of the municipal networks is usually over 90 degrees and therefore far above the temperature of the waste heat from the data centers of around 30-34 degrees.[10] To achieve the higher temperature in the district heating network, heat pumps could raise the temperature level. However, this in turn requires energy. The economic viability of waste heat utilization therefore also depends on energy prices. However, the CO_2 price included in this alone is likely to rise in the future and have a positive impact on the economic viability of such projects.

Since 2021, a pilot project has been underway in Frankfurt that is unique in this form in Germany. It provides important insights into the potential of waste heat utilization. Around 60% of a new construction project with 1,300 apartments, known as "Franky", is heated with waste heat from a data center operated by Telehouse.[11] The remaining 40% is supplied from the municipal district heating network. The waste heat from the data center is increased to a temperature of 70 degrees using heat pumps. This temperature level is sufficient because these are new buildings, whose large radiators manage with lower circulation temperatures. The challenge would be greater for existing buildings, as higher temperatures are usually required.[12] These can also be obtained from data center operations without heat pumps if the servers are cooled with water instead of air cooling. The profitability of such solutions is not yet given at the current prices for electricity and heating energy, but is likely to improve in the future. Overall, the use of waste heat is a worthwhile way to improve the energy efficiency of data centers. In addition to the development of energy prices, however, an expansion of the municipal local and district heating infrastructure is required. However, this only applies to new buildings. A study for the Frankfurt area, for example, came to the conclusion that almost three quarters of the waste heat capacity available in data centers there is currently difficult to exploit. A high potential for waste heat utilization is only seen in new data centers.[13]

Cooling

Requirements regarding the cooling systems of data centers arise on the one hand from the regulations of the Energy Efficiency Act with regard to the PUE to be achieved and the use of waste heat. There are also regulations on the permissibility of coolants. Overall, this triggers a number of innovations to achieve lower input temperatures, which offer high energy and cost-saving potential. These include underground thermal storage tanks for cooling water or the use of well or river water. Geothermal energy can also be used for cooling. In a particular project in Germany which utilizes geothermal energy, the air drawn in can be

[10] Ostler, U., 2023: Béla Waldhauser: Das EnEfG gefährdet den Datacenter-Standort Deutschland. https://www.datacenter-insider.de/bela-waldhauser-das-enefg-gefaehrdet-den-datacenter-standort-deutschland-a-1ccd73322eeee6844607e2bfc6ed7768/

[11] Lutz, H., 2021: „Das Heizen mit Datacenter-Abwärme ist auch hierzulande keine Utopie mehr". https://www.datacenter-insider.de/das-heizen-mit-datacenter-abwaerme-ist-auch-hierzulande-keine-utopie-mehr-a-713452938fad8e21a549a3d969f85d72/

[12] This argument is disputed, as the high temperatures are only needed on a few peak days a year. Cf. Lutz, H., 2021: „Das Heizen mit Datacenter-Abwärme ist auch hierzulande keine Utopie mehr". https://www.datacenter-insider.de/das-heizen-mit-datacenter-abwaerme-ist-auch-hierzulande-keine-utopie-mehr-a-713452938fad8e21a549a3d969f85d72/

[13] Orozaliev, J., 2023: Machbarkeitsuntersuchung Abwärmenutzung aus Rechenzentren in Eschborn und Frankfurt Sossenheim. Gehalten auf der Impact Dialog zur Abwärmenutzung aus Rechenzentren, Frankfurt am Main.

cooled to 18 degrees and a return temperature of 24 degrees can be achieved.[14] As a result, the data center achieves a PUE of 1.09.

A newly opened innovative data center operated by the University of Göttingen was presented at the Data Center Summit.[15] It uses an underground ice storage facility to support the cooling system, which uses an environmentally friendly natural refrigerant. The Lefdal Mine Datacenter (LMD) in Norway, which is operated by the Friedhelm Loh Group together with local investors and the local (water) power supplier, was also presented. [16] The colocation data center is located near the village of Bryggja on the Nordfjord in a former olivine mine. The operators promise particularly high server security in the mine, Tier III uptime thanks to redundant power supply, cooling and data lines, as well as ecological operation thanks to hydroelectric power and indirect cooling with cold fjord water. The Power Usage Effectiveness (PUE) is said to be 1.15.

Uninterruptable Power Supply (UPS)

A UPS system acts as a protective layer between the data center's power supply and its IT infrastructure. It makes it possible to disconnect the IT from the mains power supply if necessary and thus isolate it from unforeseen events in the power grid. The systems are designed to neutralize various incidents, including lightning strikes, voltage fluctuations, power failures and frequency changes. Overvoltage or undervoltage in particular could occur more frequently in times of increased use of renewable energy sources. UPS systems are a mandatory element according to EU standards for data centers. UPS systems consist of three main components: an energy supplier, connections to batteries or generators on the one hand and to the IT systems and electronic circuits on the other. The former ensures that electricity continues to flow as usual for a certain bridging period in the event of a power failure.[17]

For its part, maintaining a UPS has an energy requirement that is not negligible, as shown in Figure 3 on page 5, and contributes to the overall energy consumption of a data center. Technical developments in recent decades have therefore continuously increased the efficiency of UPS systems and thus reduced power consumption (see Figure 4). Innovations in this area are primarily taking place in storage technology. Batteries, especially lead batteries, which are still frequently used today, have weaknesses in terms of the environmental friendliness of the materials used. Battery-free solutions rely on flywheels, but these in turn have disadvantages such as their high mass and the structural requirements for storing them in buildings. Future technologies such as supercapacitors, which are capable of bridging voltage fluctuations, also manage without batteries. The costs and energy requirements of

[14] https://www.datacenter-insider.de/beispiele-fuer-pfiffige-effiziente-kuehllung-im-datacenter-a-0a4edfe828b5e0c79f81cda2db50415a/

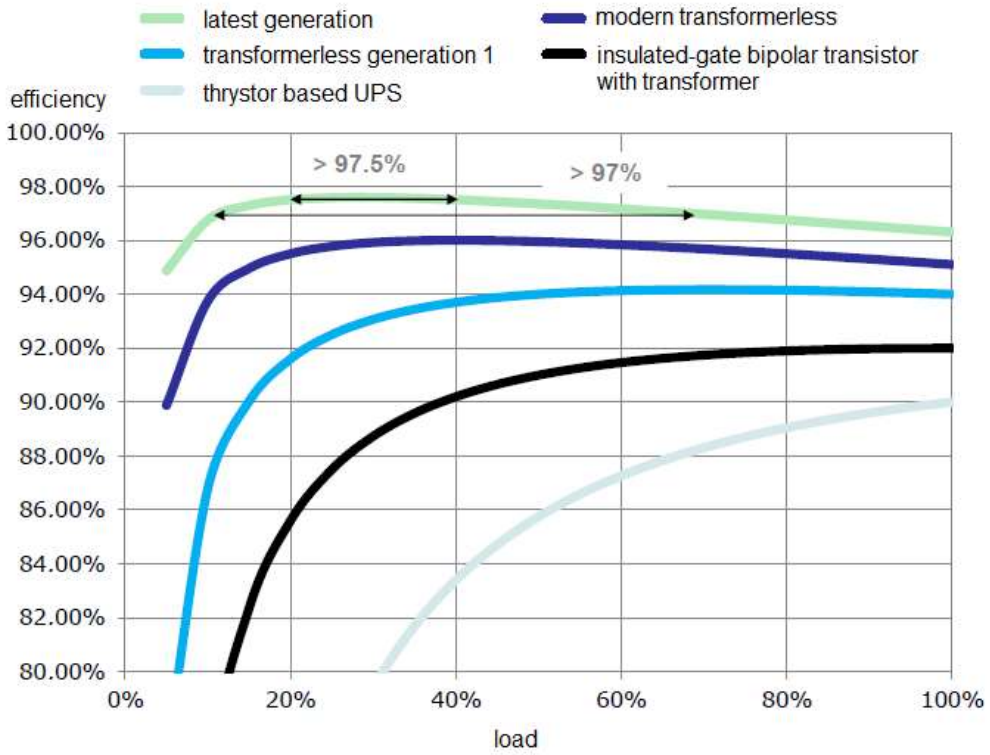
[15] The project operates under the name GWDG - Gesellschaft für wissenschaftliche Datenverarbeitung GmbH Göttingen. The joint institution of the Georg-August-Universität Göttingen - Stiftung Öffentlichen Rechts and the Max Planck Society performs the function of a computing and IT competence center for the Max Planck Society and the university computing center for the University of Göttingen. Cf. Yahyapoor, R., 2023: Strategien für ein modernes Datacenter – Von der Cloud zu KI und Supercomputing, presentation held on the Data Center Summit 2023, Bad Homburg.

[16] Ritt, W., 2023: Nachhaltigkeit im Fokus – aber wie und mit welchen Technologien? Presentation held on the Data Center Summit 2023 in Bad Homburg.

[17] Rüdiger, A., 2017: Was ist eine Unterbrechungsfreie Stromversorgung? https://www.datacenter-insider.de/was-ist-eine-unterbrechungsfreie-stromversorgung-a-669619/

UPSs also result from the fact that their functionality must be tested regularly, often every 24 hours. With diesel generators, it must also be ensured that the fuel does not degenerate due to long-term storage. One innovative option is for data centers to offer local electricity providers energy generation by generator as a second reserve for a fee.

Figure 4: Efficiency of UPSs According to Technical Design



Source: Stiedl, A. and Hümpfner, R., 2023: innovative Stromversorgung in Rechenzentren. Huawei Nürnberg Research Center.

Data storage

The considerable energy consumption of data storage technology in data centers means that innovative solutions are also being sought in this area. As an important step, it is expected that flash memory will completely replace the still widely used hard disk storage. At around 30% per year, the price decline of this technology is currently significantly higher than that of hard disks, which are only becoming around 10% cheaper per year.[18] One advantage of this technology is that the increase in storage capacity, which is constantly progressing, is not accompanied by higher power consumption, as is the case with hard disks. There are also considerable savings in power consumption, which is the strongest argument for flash memory: it is possible to reduce power consumption by 80% compared to hard disk solutions. The lower space requirement of the units, which also saves around 80% of space, is also a significant advantage. Finally, the significantly lower amount of electronic waste generated when the product life cycle is over should also be mentioned.

[18] Grau, M., 2023: Wie kommen Datenwachstum und Nachhaltigkeit in Einklang? Presentation held on the Data Center Summit 2023 in Bad Homburg; Rüdiger, A., 2023: Festplattenlose Zukunft bei Pure Storage. https://www.it-business.de/pure-storage-plant-die-festplattenlose-zukunft-a-d9b760c3ecf25cbae675c4ba1eca1a80/

Mitigation of embodied emissions

In previous Market Insights, we have looked at CO_2 emissions in the real estate sector on several occasions and analyzed the targets and challenges. In doing so, we have also highlighted the great importance of embodied emissions, i.e. emissions that arise during the construction process and have often only played a minor role in the industry's sustainability efforts to date. We have also highlighted the reasons why this is likely to change in the near future. One of the many innovations aimed at reducing construction-related emissions is 3D printing of building shells, which has been tried and tested for several years. CO_2 emissions savings here are mainly due to the composition of low-emission compressed concrete as a binding agent and the possibility of using mineral building materials that are 100% recyclable. However, due to the specific external structure of the resulting buildings, aesthetic concerns often prevail. However, for commercial buildings such as data centers, where these considerations play a lesser role, this is a promising solution.

Figure 5: Construction of a Shell for a Data Center Using the 3d Printing Process

Source: Kraus Gruppe, 2023: Ein Co-Location-Datacenter im 3D-Druck für Heidelberg IT von der Kraus Gruppe. https://www.datacenter-insider.de/ein-co-location-datacenter-im-3d-druck-fuer-heidelberg-it-von-der-kraus-gruppe-a-d1fa0373770c759991a0952d8d88f9db/

One such building was constructed in Heidelberg in 2023 on behalf of Heidelberg IT Management GmbH&Co KG (see Figure 5). The builder estimates CO2 savings of 55% compared to conventional construction with cement simply due to the alternative binder used.[19] Another welcome effect is that the manpower required for 3D printing buildings is significantly lower, which is very welcome in times of a shortage of skilled workers.

[19] Kraus Gruppe, 2023: Ein Co-Location-Datacenter im 3D-Druck für Heidelberg IT von der Kraus Gruppe. https://www.datacenter-insider.de/ein-co-location-datacenter-im-3d-druck-fuer-heidelberg-it-von-der-kraus-gruppe-a-d1fa0373770c759991a0952d8d88f9db/

Conclusion

The two parts of our Market Insights on the data center market paint a picture of an asset class that has experienced enormous growth in the past. Many of the trends that were responsible for this will continue to have an impact in the future. In the recent years, the rapid development of artificial intelligence in particular has been added, and much can be expected from this in the future. The high-performance computing behind it is particularly resource-intensive. Accordingly, the global growth prospects for the data center sector are very good. The forecasts for Germany are also predominantly positive. However, they have lost some of their confidence in the recent past, mainly due to higher energy prices since the Russian attack of Ukraine. This higher price level can also be expected in the future. However, the impact on the data center sector is less clear. It is conceivable that due to the high energy prices growth in Germany will be less dynamic than in other regions of the world. However, it is also possible that other location factors, in which Germany is very well positioned, will retain the upper hand in investors' decisions. For example, energy prices are often not seen as a decisive factor. Legal certainty, the stability of the power supply and the high level of statutory data protection in Germany are seen as more important. This also stimulates innovations, some of which we have presented.

ESG already plays a major role in the strategies of players in the data center market and will continue to do so in the future. According to surveys, the pursuit of climate neutrality is an integral part of companies' targets. This already obliges them to take concrete action. Added to this are regulations such as the new Energy Efficiency Act, which contains specific provisions for data centers. Under these framework conditions, a wide range of innovations are emerging that aim to reduce electricity consumption and save CO_2. This demonstrates the resilience of the energy-intensive industry under difficult conditions. In many cases, for example, the waste heat from a data center can be used to heat adjacent city districts. In this way, a positive contribution in the sense of the S in ESG could increase the acceptance of industrial buildings, which are often viewed with skepticism. Innovative cooling processes help to reduce the consumption of resources. The same applies to new data storage systems or the safeguarding of uninterruptible power supplies. But there are also approaches to reducing resource consumption and CO_2 emissions in construction. One example is the process of 3D printing a building shell, which is particularly suitable for data centers, as recently demonstrated by a project in Heidelberg.

High energy prices, however, pose a risk that also affects other industrial sectors. In view of the challenge of achieving climate neutrality, the security of the electricity supply in Germany is no longer without any doubt, as it was in the past. One reason for this is that the demand for electricity will increase significantly as a result of the electrification of ever larger parts of industry and transportation. In addition to the further expansion of renewable energies and electricity storage options, the expansion of the grid must also progress much faster. In this context, it is worth mentioning that, according to a manager from the industry, the electricity requirements of a 30 MW data center in Frankfurt, which is registered today, can only be fulfilled from 2030 onwards.[20]

In addition to the energy supply, however, there are other important issues that need to be addressed in order to secure Germany's competitiveness. One of these is the growing labor shortage, which is also affecting the real estate and construction industries. We have already pointed out several times in previous Market Insights that, in view of demographic

[20] Christina Mertens of Virtus in Immobilien Zeitung, November 30, 2023.

developments, a social debate on qualified immigration should be opened. Another important obstacle to growth, which we have already addressed, is the acute shortage of housing. Companies are finding it increasingly difficult to find new employees because applicants cannot find suitable accommodation for themselves and their families on the housing market. Here, too, Germany is in a situation that requires decisive action. However, opportunities are often limited by bureaucratic cumbersomeness, long-lasting approval processes and an overload of regulations and reporting obligations. Here, politicians would be well advised to follow up the announcements regarding the reduction of bureaucracy that have been repeated for decades with action.

Glossary[21]

4K video: 4K video refers to ultra-high-definition (UHD) video content characterized by its significantly higher resolution compared to traditional high-definition (HD) video formats. It encompasses video formats with a horizontal resolution of approximately 4,000 pixels, leading to a resolution of around 3840 x 2160 pixels, also known as 2160p. The increased pixel density of 4K video results in sharper, more detailed imagery and offers a superior viewing experience on compatible displays.

5G network: 5G, the fifth generation of wireless technology, represents a significant advancement in telecommunications networks. It promises faster data speeds, lower →latency, and enhanced connectivity compared to previous generations (such as 4G/LTE). With theoretical speeds up to 20 Gbps, 5G technology facilitates near-instantaneous data transfer, enabling a multitude of innovative applications.

Artificial Intelligence (AI): AI refers to the simulation of human intelligence processes by computer systems. It encompasses a broad range of technologies and techniques that enable machines to perform tasks that typically require human intelligence. These tasks include learning, reasoning, problem-solving, perception, language understanding, and decision-making. AI applications span various domains, from robotics and healthcare to finance and entertainment. →*generative AI*

Big data: Big data refers to vast and complex datasets characterized by their volume, velocity, and variety. It encompasses large amounts of structured and unstructured data generated from various sources, including sensors, social media, transactions, and more. The analysis of big data requires specialized tools and technologies capable of processing, storing, and extracting valuable insights from these massive datasets. Big data analytics involves applying advanced algorithms and analytics techniques to uncover patterns, trends, correlations, and other valuable information that can be used for decision-making, business intelligence, research, and innovation.

Bitkom: Bitkom is a leading digital association in Germany, representing companies in the digital economy, technology, and telecommunications sectors. As one of the largest associations of its kind in Europe, Bitkom advocates for the interests of its members, promotes digital innovation, and shapes policies related to digitalization.

Cloud computing: Cloud computing is a technology that enables the delivery of computing services — including servers, storage, databases, networking, software, and more — over the internet. It provides on-demand access to a shared pool of configurable computing resources, allowing individuals and organizations to use and pay for services as needed. This model offers scalability, flexibility, and cost-efficiency by eliminating the need for on-site infrastructure maintenance and management. Users can access applications, store and process data, and utilize computing power remotely through cloud service providers. A private cloud refers to a cloud computing environment dedicated exclusively to a single organization. It is hosted either on-premises within the organization's data centers or by a third-party service provider. The infrastructure and services in a private cloud are tailored to meet the specific needs of the organization, offering greater control, security, and customization. A public cloud involves the delivery of computing services—such as

[21] This glossary was created with the support of Chat-GPT.

servers, storage, databases, and more—by a third-party cloud service provider over the internet. These services are shared among multiple organizations and users on a pay-as-you-go basis, making it a cost-effective option. Cloud computing is categorized into three primary service models: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). IaaS offers virtualized computing resources such as virtual machines, storage, and networking components. PaaS provides a platform allowing developers to build and deploy applications without managing the underlying infrastructure. SaaS delivers ready-to-use software applications accessible via the internet.

Computer Center: The terms and "computer center" ("Rechenzentrum") and "data center" are often used interchangeably, but there can be some nuances in their meanings, depending on context and regional preferences. "Computer center" could imply a more narrow focus on computing operations and hardware management, while "data center" might encompass a broader range of functions, including storage, networking, and data management in addition to computing.

Connection node: A connection node, also known as a network node, is a crucial element in computer networks. It acts as a point for devices to communicate and share data. Examples include routers, switches, hubs, and gateways. These nodes manage and direct data flow within networks, ensuring efficient communication between devices and systems. Internet connection nodes form the backbone of the internet infrastructure, ensuring the efficient and secure transmission of data between interconnected devices and networks. Their strategic placement and configuration significantly impact the speed, reliability, and security of internet connections.

Data center: A data center is a central physical facility that houses enterprise computers, network, storage and other IT equipment to support business operations. The computers in a data center contain or support business-critical applications, services and data. Data centers come in all sizes - they can fill a closet, a dedicated room or a warehouse. Some companies with a lot of IT equipment in their data centers may need more than one data center. Companies can also rent server space and have their data center maintained by third-party providers. A data center can expand beyond a physical facility by adding operations or storage with a private or public cloud. In a virtualized data center, virtualization technologies are used to separate the physical resources from the software and applications that run on them, allowing for greater resource utilization. →*computer center*

DE-CIX: DE-CIX, short for "Deutscher Commercial Internet Exchange", is the world's largest and most renowned →Internet Exchange Points (IXP). Headquartered in Frankfurt, Germany, DE-CIX operates numerous Internet Exchange platforms globally, facilitating the direct exchange of internet traffic between →internet service providers (ISPs), and other network operators. It enhances connectivity, reduces →latency, and optimizes internet traffic routes. DE-CIX serves as a vitl location for global internet traffic exchange due to its strategic geographic position and the concentration of international network infrastructures.

Edge computing: Edge computing refers to a decentralized computing paradigm that brings computation and data storage closer to the location where it's needed, rather than relying solely on centralized data centers or →cloud computing environments. This approach processes data near the "edge" of the network, closer to the devices generating or consuming the data. Edge computing reduces →latency, optimizes

bandwidth usage, and enables faster response times for critical applications. It involves deploying computing infrastructure, such as servers, data analytics, and content delivery networks, in proximity to where data is generated. Edge computing finds applications in scenarios like →IoT devices, autonomous vehicles, and smart infrastructure.

Generative artificial intelligence (generative AI): Generative AI is a subset of →*artificial intelligence* which focuses on creating content or data rather than analyzing or interpreting existing information. This technology uses machine learning algorithms to generate new, original content. Generative AI can create images, texts, music, videos, and other media, often producing highly realistic and novel outputs.

Hybrid cloud computing: A hybrid cloud strategy involves the use of a combination of public and private →*cloud computing* services, as well as →*on-premises* infrastructure. It allows organizations to leverage the benefits of both environments by integrating and managing workloads across multiple platforms. This approach offers flexibility, scalability, and the ability to optimize resources based on specific needs. For instance, sensitive data can be kept on a private cloud for security reasons, while less critical applications may utilize the cost-effective public cloud.

Hyperscaler: Hyperscaler refers to a select group of companies that provide cloud computing services on a massive scale. These companies operate vast data centers (often also called hyperscalers) with extensive computing resources, storage capacity, and global networking infrastructure. They offer cloud services to businesses, organizations, and individuals worldwide. The hyperscale infrastructure of these companies allows them to handle enormous amounts of data, accommodate high traffic volumes, and provide scalable computing resources on-demand. Notable hyperscalers include industry giants like Amazon Web Services (AWS), Microsoft Azure, Google Cloud Platform (GCP), and others.

Infrastructure as a Service (IaaS): →*cloud computing*

Internet Exchange Point (IXP): An Internet Exchange Point (IXP) serves as a physical location where multiple →internet service providers (ISPs) and networks come together to exchange internet traffic. IXPs facilitate the direct interconnection of networks, allowing them to exchange data and efficiently route traffic between their respective networks.

Internet of Things (IoT): The Internet of Things (IoT) refers to a network of interconnected physical devices, sensors, and objects embedded with sensors, software, and connectivity capabilities that enable them to collect and exchange data. These devices can range from everyday objects like home appliances, wearables, and vehicles to industrial machinery and smart city infrastructure. IoT devices are designed to gather and transmit data over the internet or other networks, allowing them to communicate with each other, share information, and perform automated tasks without human intervention. They collect real-time data from their surroundings, enabling monitoring, analysis, and control of various systems and environments.

Internet Service Provider (ISP): An Internet Service Provider (ISP) is a company or organization that provides access to the internet and related services to individuals, businesses, and other entities. ISPs offer various types of internet connectivity,

including broadband, fiber-optic, DSL, cable, satellite, and wireless connections. ISPs serve as the bridge between users and the internet, delivering connectivity through their network infrastructure.

IP network: IP (Internet Protocol) networks are communication networks that utilize the Internet Protocol for transmitting data packets between devices. These networks form the backbone of the internet and are fundamental to modern digital communication. IP networks allow devices, such as computers, smartphones, servers etc. to connect and communicate with each other across the globe. Each device on an IP network is assigned a unique numerical label known as an IP address, enabling data packets to be routed accurately to their destinations.

Latency: Latency refers to the time delay between the initiation of a data transfer and the moment when the transfer begins or completes. It is commonly used to describe the time (=latency time) taken for data to travel from its source to its destination, typically measured in milliseconds.

Machine learning (ML): Machine learning is a branch of →*artificial intelligence* which focuses on developing algorithms and models that enable computers to learn from data and make predictions or decisions without being explicitly programmed for each task. It involves the use of statistical techniques to enable systems to improve their performance on a specific task over time as they are exposed to more data. The goal of machine learning is to enable computers to learn patterns and relationships from data to make accurate predictions or take actions.

Mobile connectivity: Mobile connectivity refers to the ability of mobile devices, such as smartphones, tablets, and →IoT gadgets, to connect to telecommunications networks for data exchange and communication. It encompasses the technologies and infrastructure that enable these devices to establish connections and access the internet or other networks. Mobile connectivity relies on cellular networks provided by telecommunications companies.

Mulitcloud computing: A multicloud (→*cloud computing*) strategy involves using services from multiple cloud providers to avoid vendor lock-in, optimize performance, and diversify risk. Organizations employing a multicloud approach utilize different cloud services from various providers simultaneously. This strategy enables them to select the best-suited services from different vendors based on features, costs, geographic availability, or specific functionalities. It helps mitigate risks associated with relying on a single provider and allows for greater customization and flexibility in meeting diverse business needs.

On-premise data center: An on-premise data center refers to a facility owned, managed, and operated by an organization within its own physical premises or dedicated location. It houses computing hardware, servers, networking equipment, storage, and other infrastructure required to store, process, and manage data and applications.

Platform as a Service (PaaS): →*cloud computing*

Power Usage Effectiveness (PUE): Power Usage Effectiveness (PUE) is a metric used to assess the energy efficiency of a data center. It is calculated by dividing the total energy consumption of a data center by the energy consumed by the IT equipment. A lower PUE value indicates higher energy efficiency, as it implies that a larger

proportion of the energy is used by the IT equipment rather than supporting infrastructure like cooling and lighting.

Private cloud computing: →*cloud computing*

Public cloud computing: →*cloud computing*

Software as a Service (SaaS): →*cloud computing*

Zettabyte: A zettabyte is a unit of digital information measurement, representing an enormous volume of data. It is equivalent to one sextillion bytes, or 2^{70} bytes. To put it into perspective, one zettabyte is a thousand exabytes, a million petabytes, a billion terabytes, or a trillion gigabytes.

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