DATA CENTER IMPACT REPORT DEUTSCHLAND

2024

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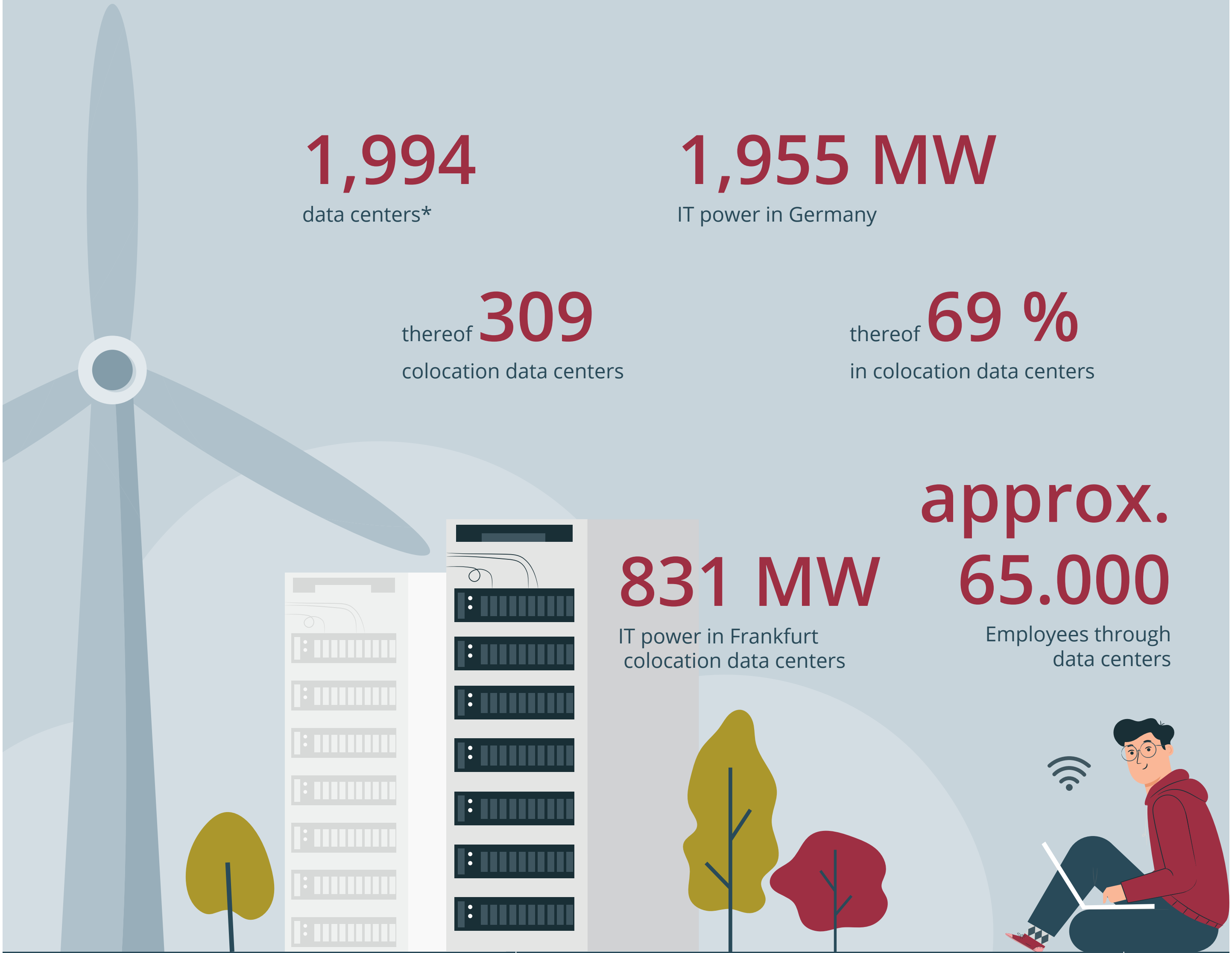
THE DATA CENTER MARKET IN FIGURES



1,994
data centers*

1,955 MW
IT power in Germany

thereof **309**
colocation data centers

thereof **69 %**
in colocation data centers

831 MW
IT power in Frankfurt colocation data centers

approx. 65.000
Employees through data centers

88 %
Energy use from RE in colocation data centers

10.4 billion €
German colocation and hyperscale data centers contribute to GDP annually

28 %
of the colocation data centers utilise the waste heat

* Colocation and enterprise data centers > 50 kW

EDITORIAL

DEAR READERS,

Hardly any situation in our modern everyday lives is conceivable without digital data – whether we are exchanging messages on our smartphone, checking public transport connections in an app or following the day's news online on the way to work. But the control of large parts of critical infrastructure – traffic management systems, power plants, heat and electricity grids – also rely on uninterrupted data streams.

This data is stored, processed, and transmitted in data centers. In recent decades, these data centers have mostly been located in secret, away from social debate, where they ensured the reliable provision of the services that we all use – directly or indirectly.

Data centers have recently become the focus of public attention due to the German Energy Efficiency Act, which places explicit efficiency requirements on existing and new facilities. Regulatory initiatives such as these make it clear that it is necessary to create transparency with a solid data basis – about the characteristics and general state of the market, but also about the challenges, opportunities and potential. However, until now there have been no precise figures on the number of data centers in Germany and the IT capacity they provide. Similarly, employment figures, data on investments and the contribution to the industry's gross domestic product were based on estimates.

In order to create a solid data basis and identify relevant developments, the German Datacenter Association has commissioned a study, the results of which are now available to you. After all, potential can only be realistically assessed if reliable data is available for decision-making.

The **DATA CENTER IMPACT REPORT GERMANY 2024** is the first attempt to measure the German data center market. The study also looks at the socio-economic impact of the German data center industry.

The results are positive: despite the many challenges – availability of electricity and space, regulation, bureaucracy, shortage of skilled workers – the data center market in Germany is experiencing enormous growth. This growth is being fueled by the increased demand for cloud services, big data analyses and the integration of AI technologies. It can be assumed that the capacity of the colocation data center market will more than double from 1.3 GW to over 3.3 GW in the next five years.

Contrary to all pessimistic forecasts for the German economy, the data center industry is experiencing a real boom: The capacity forecasts of the colocation market segment alone justify investments of over 24 billion euros over the next five years. Added to this are the multi-billion euro investment programmes of hyperscalers, which will extend far into the next decade – not including the individual and extremely costly server infrastructure. Instead of migrating, operators are expanding their capacities and new operators are entering the market. In order to realise these investments in Germany's

infrastructure, political action and foresight are required. With the key figures now available, we will provide important impetus in discussions with decision-makers from politics and business in order to generate an understanding of the special features of the industry and to sustainably improve the framework conditions for data center operations in Germany.

The German Datacenter Association will continue to update the data on an annual basis in order to document the current status of the market. In addition to the existing data, we will analyse further key figures in the coming years.

We wish you an insightful reading of the **DATA CENTER IMPACT REPORT GERMANY 2024** and look forward to the exchange!

Your

Anna Klaft Chairman of the Executive Board	Peter Pohlschröder Deputy Chairman of the Executive Board

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MANAGEMENT SUMMARY

FOREWORD

Germany needs high-performance data centers for its future. Since 2010, the demand for IT computing power has increased tenfold. The advancing digitalisation of the economy, public administration and all areas of life is only possible with a high-performance IT infrastructure. Data centers are the cornerstones of this infrastructure. The main focus of the data center industry is on high-availability data centers and fail-safe operation so that the digital services that ensure modern life are not interrupted. Nearly every app on a smartphone, as well as large parts of our critical infrastructure – hospitals and emergency services, airports, power stations, ministries, financial transaction providers – are themselves dependent on data centers.

GERMAN DATA CENTERS GUARANTEE OUR DIGITAL SOVEREIGNTY

The data centers in Germany make it possible to store and process sensitive data and applications securely and reliably within the country – in accordance with German (e.g. BDSG) and European (GDPR) legal standards. Thus guaranteeing self-determined control over the collection, storage, use and processing of our own data. This reduces the risk of data and applications being controlled or even misused by unauthorised third parties and ensures the independence and integrity of critical systems. This data sovereignty is an important part of our country's digital sovereignty.

DIGITALISATION DRIVES SUSTAINABILITY FORWARD

Digitalisation saves CO2 emissions: Digital technologies are helping to reduce greenhouse gas emissions worldwide by up to 15 %[1]. This is made possible by the use of digital alternatives to analogue processes – for example, video conferencing replaces domestic flights and working from home replaces travelling to the workplace. Video conferences save up to 99.5 % CO_2[2] compared to regular events. The use of advanced technology also makes it possible to optimize processes resource consumption: Computing centres can collect and analyse large amounts of data in real time in order to improve the efficiency, agility and competitiveness of companies. Artificial intelligence (AI), high-performance computing and the bundling of data enable better analyses of automation in industrial production and the intelligent control of power grids or road traffic.

GERMAN DATA CENTERS ARE PIONEERS IN THE USE OF RENEWABLE ENERGIES AND ARE AMONG THE MOST EFFICIENT IN THE WORLD

Although the basic prices for electricity are similar throughout Europe, the costs in Germany are almost twice as high as in other European countries due to grid fees, taxes and levies – before the energy crisis, they were sometimes six times as high[3]. Energy costs account for around half of the operating expenses of German data centers. As data centers are assigned to the service sector, the operating companies do not benefit from the tax advantages that the manufacturing industry enjoys. As a data-processing sector, it certainly faces similar challenges to industry, but does not benefit from its favourable tax treatment. Increases in energy efficiency and strategies such as acquiring Power Purchase Agreements (PPA) in order to purchase low-cost electricity from renewable sources are the positive effects.

[1] https://ec.europa.eu/commission/presscorner/detail/de/fs_20_281 (last accessed on 01/03/2024).
[2] https://kommunikation.uni-freiburg.de/pm/2021/digitales-einsparpotenzial (last accessed on 01/03/2024).
[3] https://www.bitkom.org/Presse/Presseinformation/Deutsche-Rechenzentren-haben-hoechste-Stromkosten-in-Europa (last accessed on 01/03/2024).

However, it is not only out of economic interest, but also out of corporate and social responsibility that data center operators design their facilities to be as sustainable, resource- and energy-efficient as possible.

Thanks to continuous efficiency improvements, the use of new technologies and artificial intelligence, data center operators have succeeded in decoupling the absolute power consumption from the rate of increase in data volumes: measured in terms of workloads in data centers, performance increased eightfold between 2010 and 2020[4], but the energy requirement per workload was 12 times lower in 2020 than in 2010[5]. Initiatives such as the Climate Neutral Data Centre Pact, whose more than 100 signatories are committed to climate-neutral data center operations by 2030, manifest this attitude.

CLASSIFICATION OF THE STUDY RESULTS

The Data Center Impact Report Germany 2024 looks at the dynamic growth and economic impact of the German data center industry in 2024 and beyond. It highlights the industry's central role in supporting the digital transformation in various sectors and emphasizes its contribution to strengthening the digital infrastructure in Germany. The analysis shows the accelerated expansion of the sector, driven by the increasing demand for cloud services, big data analytics and the integration of AI technologies.

The study commissioned by the German Datacenter Association (GDA) presents quantitative results based on various research methods. Secondary surveys were used to establish a solid database for colocation and hyper-scale data centers in order to identify and understand relevant trends and developments.

In addition, two surveys were conducted: one with 29 leading decision-makers in colocation data centers and another with 203 decision-makers in enterprise data centers.

The results obtained show that the industry has created significant economic value in Germany, including substantial investment, an increase in direct employment opportunities and a notable contribution to the gross domestic product (GDP). The data collected emphasizes the strategic importance of computing centers for Germany's digital sovereignty and economic resilience.

The report describes the introduction of energy-efficient technologies and sustainable practices in computing centres, reflecting the industry's commitment to reducing its environmental footprint. This aspect is particularly emphasised by the sector's switch to renewable energy sources and the implementation of advanced cooling mechanisms to improve Power Usage Effectiveness (PUE).

The study also outlines future challenges and opportunities. The results of the study show that regulatory support and investment in green technologies are necessary in order to create planning and legal certainty and thus promote growth and innovation. The study makes it clear that a policy is needed that supports the development of a robust, secure and sustainable digital infrastructure. After all, a sustainable and climate-friendly economy is only possible with favourable framework conditions for a strong digital infrastructure.

The most important findings of the study are summarised below and classified from the perspective of the German Datacenter Association.

[4] https://www.borderstep.de/wp-content/uploads/2021/03/Borderstep_Rechenzentren2020_20210301_final.pdf (last accessed: 01/03/2024).
[5] https://www.eco.de/presse/eco-studie-rechenzentren-sind-garant-fuer-nachhaltige-digitalisierung-in-europa/ (last accessed: 01/03/2024).

GROWTH AND ECONOMIC CONTRIBUTION

The data center sector is experiencing significant growth and makes an important contribution to the German economy. It forms the basis for the country's efficient digital development. This growth is being driven by the increasing demand for digital services, cloud computing and digital transformation in all sectors. The Internet of Things (IoT), the 5G transmission standard and developments in the field of artificial intelligence are ensuring that the need for data processing is increasing exponentially. The legal and social requirements for data protection, data security and data sovereignty necessitate the storage and processing of data in Germany. It can be assumed that the IT capacity of colocation data centers in Germany will increase from the current 1.3 GW to 3.3 GW by 2029.

On the basis of a conservative growth model, this study forecasts continuous investments of around two billion euros per year in the expansion of colocation and hyperscale data centers. If, on the other hand, the predicted growth in IT capacity is quantified using market values for construction costs for the expanded data center, estimated average land prices and average space efficiency, investments of over 24 billion euros can be expected for the expansion of colocation capacities by 2029. Added to this are the 4.2 billion investment programmes of hyperscalers Google and Microsoft, which will last until 2030. In addition to the costly server infrastructure.

These investments will initially focus on suitable properties, their energy development and the data center architectures to be built in a few agglomerations. First and foremost, the Frankfurt am Main metropolitan region and the Berlin-Brandenburg metropolitan region, which represent the two German Tier I locations.

TABLE: Investments in the construction of colocation data centers (€ million), forecast to 2029

	2024	**2029**
DC capacities	1,300 MW	3,300 MW
Extension	2,000 MW	
Construction costs (fully fitted)	12 million EUR/MW	EUR 24,000 million
Property prices	700 EUR/m² Ø	
Property area	500 m²/MW Ø	
Property investment	0.35 million EUR/MW	EUR 700 million
		EUR 24,700 million

The sector provides around 65,000 direct, indirect and induced jobs in Germany. The general trend on the labour market is also evident in data centers: 65% of the companies surveyed outside the Frankfurt am Main metropolitan region stated that the shortage of skilled workers was the biggest challenge for their companies. GDA will therefore present the industry even more strongly to the public as an attractive employer and actively participate in the necessary adaptation of training and further education programmes. Data centers offer a wide range of future-proof and well-paid opportunities, particularly for dual vocational training and advanced training or qualified lateral entry.

In addition, there is a direct and indirect contribution to GDP currently totalling approx. 10.4 billion euros for 2024. This contribution is forecasted to more than double to 23 billion euros by 2029.

In addition to the socio-economic effects, the provision of critical infrastructure for Germany's economic development through digital transformation is of even greater importance. With the increase in AI and the correspondingly equipped high-density data centers, which have an even greater power requirement, even more efficient technical solutions, for example in cooling technology, are being driven forward.

Limited availability of land and electricity, high electricity prices and lengthy authorization procedures are slowing down the industry's growth. In addition, regulations – such as the European Energy Efficiency Directive (EED), the German Energy Efficiency Act (Energieeffizienz-Gesetz, EnEfG) and regional requirements – place strict limits on developments.

SUSTAINABILITY AND ENERGY EFFICIENCY

Data centers in Germany are constantly working on optimizing their energy efficiency and sustainability and are focusing on reducing their environmental impact. The majority of IT power in Germany, around 70% (1,360 MW of a total of 1,955 MW), is provided by colocation data centers, which are significantly more energy-efficient than enterprise data centers due to their scale effect.

The industry is a pioneer in the use of electricity from renewable energy sources. Even today, 88% of the electricity consumed by colocation data centers comes from renewable sources, underlining the sector's efforts towards sustainability in the technology industry. 69% of the colocation companies surveyed stated that they purchase electricity via one or more Power Purchase Agreements (PPA). Under this power purchase agreement, the customer undertakes to purchase electricity directly from a renewable energy project over a longer period of time. In return, they receive a reduced electricity price. Through PPAs, the power generation industry is strongly committed to the expansion of renewable energies in Germany – many of these investments would not be realisable without the financial security provided by PPAs.

Modern colocation data centers that rent server space to customers are generally far more efficient to operate than company-owned data centers, as they bundle services and regularly invest in environmentally friendly upgrades, which is confirmed by the data in this report. While the PUE value of colocation data centers averages 1.3, an average PUE value of 1.57 was determined for enterprise data centers. However, the following should be noted when considering the PUE value of 1.3: The 29 colocation provider surveyed include both organisations that operate a large number of different data centers, which in turn provided an average value for their facilities, as well as operators of individual data centers that only provided their real PUE value. The PUE value was also not weighted according to the proportion of IT capacity.

As the Energy Efficiency Act affects all data centers in Germany with a capacity of 300 kW or more, it can be assumed that companies will increasingly outsource their enterprise data centers to colocation facilities or the cloud. However, there is no clear trend from enterprise data centers to the cloud. Rather, corporate IT environments are increasingly developing into hybrid architectures, some of which are located in various cloud models, others in enterprise or colocation data centers.

Parallel to this concentration on colocation and hyperscale data centers, the results of the report point to an increase in edge data centers. In particular for data from decentralised applications such as business-related AI, Industry 4.0 or smart cities. It can be assumed that data centers, similar to other municipal infrastructures such as water or electricity plants, will bring the digital future to all municipalities and cities.

In terms of waste heat potential from data centers, the study concludes that 28% of the colocation operators surveyed are already able to release their waste heat for further use and are already doing so. A further 31% of respondents stated that they were investing in the necessary technology. In general, there is a great willingness among operators to utilise the heat generated from renewable electricity.

CONCLUSION

The sector faces a variety of challenges such as the scarce availability of space and electricity, a high electricity price, complex authorisation procedures and complex regulations. Despite all these challenges, Germany has significant locational advantages that are decisive for the establishment of data centers and promote growth in the sector.

In addition to DE-CIX in Frankfurt am Main, there are four other international Internet exchange points in Germany. The central location in Europe and the dense backbone network ensure the interconnectivity of the country's data centers. Germany has very high data protection standards, including the General Data Protection Regulation (GDPR), and ranks second behind Ireland in the European data protection ranking. It also has the highest standards for the construction and operation of data centers in terms of fire protection, data security and certification. Last but not least, good weather conditions and a low threat level from external influences such as natural disasters, terror or power outages making the country a preferred location for data centers. The German data center industry is at a crucial point where it should use its growth and sustainability efforts to consolidate its position in the European and global digital economy.

"DATA CENTER INDUSTRY BOOMING: CONTINUING TO GROW DESPITE CHALLENGES"

To achieve this, however, continuous investment in technology, personnel development and regulatory adaptability is required. Investors are aware of this need. Nevertheless, the sector is booming like no other industry in Germany.

The GDA believes that Germany's digital infrastructure must be strengthened. The international locational advantage that already exists must not be jeopardised. For this reason, GDA continues to advocate close dialogue with politicians and administrators at local, national and European level in order to improve the framework conditions for the benefit of the industry.

Both the Energy Efficiency Act, which obliges data centers to offer waste heat, as well as the Heat Planning Act and municipal heat planning are driving the further use of waste heat generated during server operation: The Heat Planning Act aims to decarbonise heating networks by 2030. Municipal heat planning is a key instrument for strategically planning and implementing the transformation of the municipal heat supply. The goal is a completely fossil-free heating network by 2045.

"DATA CENTERS ARE AN ACTIVE PART OF CLIMATE POLICY"

Data centers can make a substantial contribution to this with the waste heat produced from renewable electricity – provided that they are integrated into neighbourhood development at an early stage, the heating network infrastructure is expanded and older networks are upgraded. In practice, however, there are still many questions that require binding clarification. For example, the requirements of the EnEfG regarding the connection of the data center to the heating network or the assumption of costs for upgrading the waste heat temperature to the level of the heating network are not complete and need to be made more specific in order to create planning and legal certainty for all parties involved. Only in this way can the use of waste heat from data centers succeed in terms of a sustainable circular economy.

The GDA emphasises the importance of the multi-stakeholder approach for the planning and implementation of waste heat projects. Cooperation models between data centers and grid operators, energy suppliers, urban planners and many other players can find individual solutions with combined expertise and tackle challenges in a targeted manner. The Bytes2Heat platform[6] shows examples of successful projects.

"DATA CENTERS ARE THE SOURCE OF REGIONAL DEVELOPMENT AND LOCAL DIGITALISATION"

In addition to the upcoming tasks relating to the expansion of digital and energy infrastructure, data centers are becoming increasingly important for further economic and regional development. The establishment of a data center is always an investment in the region's infrastructure, and the location benefits in several ways: starting

[6] Bytes2Heat is a consortium project of the Deutsche Unternehmensinitiative Energieeffizienz e.V., empact engineering GmbH and the IER and IVR institutes at the University of Stuttgart. The project is funded by the Federal Ministry for Economic Affairs and Climate Protection.
Link: https://www.bytes2heat.de (last accessed: 01/03/2024).

with the necessary connection to the fibre optic network, the construction of transformer stations and power lines, the redevelopment and reduction of wasteland and the supply of waste heat as a contribution to the municipal heat supply.

In the future, data centers are conceivable as municipal or regional growth centres that provide data services, waste heat and other investment incentives for companies and citizens. Approaches to this can already be seen in neighbourhood developments in which data centers play a central role in planning.

The German Datacenter Association sees itself as the voice of the industry and as an intermediary between data center operators and political decision-makers at European, federal and municipal level. The purpose of this study is to map the development trends and challenges of the German IT infrastructure more precisely and to identify the need for political regulation. The German Datacenter Association will therefore continue to actively seek close dialogue with Brussels, Berlin, Frankfurt and many other regions in order to promote further investment in Germany.

TAXONOMIE OF DATA CENTERS

The taxonomy of data centers can be systematised using various criteria in order to classify the numerous typologies and functions of these facilities. These criteria include the size, purpose, type of location and the type of services provided. This study focuses on colocation data centers (multi-tenant data centers) and hyperscale data centers. In-house data centers (single-tenant data centers) are also taken into account as they fulfil similar requirements and employ similar specialists. Like colocation and hyperscale data centers, company-owned data centers are also geared towards the goal of ensuring secure and efficient accommodation and hosting of IT equipment, IT infrastructure, data and applications. The growing importance of data processing has led to the development of new definitions for different types of data centers in recent years.

DEFINITIONS

DATA CENTERS WITH ONE TENANT ENTERPRISE DATA CENTERS

- Data centers and server rooms (+10 sqm server room)
- Data centers of managed service providers (IT services/hosting, but no customer access)
- Crypto mining facilities (no colocation; can also be >10MW)

HYPERSCALE DATA CENTERS (designed for large companies such as cloud service providers that require massive storage and computing capacity (e.g. Amazon Web Services (AWS), Microsoft, Google, Alibaba, IBM, Meta, Oracle, usually >20 MW)

- These companies are investing heavily in the expansion and development of their data centers in order to meet the growing demands of their customers. They play a central role in providing the infrastructure for the modern internet, including cloud computing, artificial intelligence, data analysis and much more.
- Hyperscalers operate their own data centers and often work together with specialised data center operators in Germany and rent the corresponding capacities.

MICRO DATA CENTERS (<10 sqm data floor) are not taken into account. Due to the diversity and different areas of application of micro data centers in small and medium-sized enterprises, the collection of such specific data is very challenging.

MULTI-TENANT OR COLOCATION DATA CENTERS

- RETAIL COLOCATION (customer contracts <1 MW): Data centers that rent customers space in a data center, a limited number of servers, IT infrastructure such as rack units, server cabinets or even entire rooms or halls. As a rule, the contractually agreed workload is a maximum of 1 MW per customer.
- WHOLESALE COLOCATION (customer contracts >1 MW): Data centers that rent out larger areas, usually rooms or halls, sometimes also server areas, with a contractually agreed workload of 1 MW or more.
- BUILT-TO-SUIT or powered shell, core and core shell (1 customer, contract >1 MW): Data centers that are leased to a single major customer, e.g. a hyperscaler or a large IT company, and are often built specifically for this customer.

INTRODUCTION

Data centers are a fundamental component of the digital infrastructure and make a significant contribution to economic and social development in Germany. They are essential for the storage, processing and exchange of critical data, which is essential for the digital transformation of both the economy and society. In their function as central hubs for the internet, cloud services, digital media, business applications and technologies such as artificial intelligence (AI), data centers play a key role in the implementation of data and digital strategies. They allow companies and organisations to provide digital services and applications in a secure and efficient manner, making a significant contribution to economic prosperity and innovation. The reliability and security of these infrastructures are of critical importance in today's data-intensive world. Furthermore, the existence and accessibility of high-performance

Data centers are a key factor in companies' choice of location, especially in technology-oriented, financial and e-commerce sectors as well as for research and development of key technologies. It is expected that the data center sector in Germany will see considerable investment in the double-digit billion range in the coming years, with Frankfurt am Main standing out as the leading European location in terms of both the number of facilities and the volume of investment.

Data centers make a substantial contribution to the German economy by increasing gross domestic product (GDP) and creating numerous jobs.

In view of the increasing relevance of sustainability goals, data centers are increasingly coming under the spotlight.

The focus of debates on energy efficiency and the reduction of the CO_2 footprint. Innovations in cooling technology, the use of renewable energy sources, the development of systems for energy recovery and the use of waste heat show ways in which data centers can reduce energy consumption and thus contribute to achieving climate targets.

It turns out that colocation and cloud data centers offer advantages over enterprise data centers in terms of efficiency. This is because basic infrastructures such as cooling, power supply, security and network connectivity are provided by the operator and shared by multiple users.

OBJECTIVES

As the industry association, the German Datacenter Association e.V. (GDA) has commissioned the independent research company Pb7 Research to systematically analyse the data center market in Germany and to classify the impact of the industry at an economic and social level on an annual basis.

The primary aim of this study is to generate a sound data basis and analyses in order to understand the economic and social effects and identify trends for future developments that can be used for the industry.

METHODOLOGY

Various research methods and analyses were used to conduct the study. Desk research was used to establish a solid database for colocation and hyperscale data centers in order to identify and understand relevant trends and developments. This is used to create models to quantify the various segments of the data center market, including their social and economic impact. In addition, two surveys were conducted: one with 29 leading decision-makers in colocation data centers and another with 203 decision-makers in enterprise data centers. The results of these surveys are presented in the report and are used as a basis for quantifying various market aspects. Detailed information on the methodology can be found from page 61 of the report.

FIGURE 1: Research approach

DATA CENTER DATABASE

- Market sizing
- Construction plans and investments
- Forecasting
- Geographical segmentation
- Economic impact

↑

OTHER SOURCES

Including publicly available statistics, benchmark data

DATA CENTER SURVEY

- Growth by region
- Service categories
- Sustainability (electricity, water, residual heat)
- Key challenges (shortage of skilled labour, availability of electricity and space, etc.)
- Technological trends
- Investments
- Effects of the regulations

COMBINED DATA

- Utilisation share of renewable energies
- Growth by region
- Socio-economic effects

OVERVIEW

Data centers, in combination with the fixed and mobile network infrastructure, form the basis of the digital infrastructure. The networks act as a means of transport for data, originating in the data centers and ultimately reaching the end user. Given the high demand for data within the EU or stored nationally, as well as the demand for data sovereignty and the need to respond to the rapid provision of data, the local availability of data centers is essential. This is in line with the requirements of both citizens and consumers as well as companies, for whom digitalisation is of central importance for increasing competitiveness. As a result, the primary socio-economic importance of data centers lies not in investment and employment, but in the quality of the digital infrastructure.
Organisations are increasingly reliant on digital tools to guarantee their functions and services. Professional data centers offer these organisations – from small and medium-sized enterprises (SMEs) to large corporations and the public sector – the opportunity to house computers and servers in a highly secure environment that ensures high continuity and the necessary connectivity. The geographical proximity to other technology companies enables direct connections with minimal latency, which is particularly advantageous for companies and users of cloud services such as Microsoft 365, Zoom or Google Cloud Platform.

Germany also plays an important role internationally in the field of digital infrastructure. The DE-CIX in Frankfurt am Main, for example, is the largest internet hub in Europe and the second largest in the world; a large proportion of global internet traffic is routed via Frankfurt am Main. Although large technology companies are increasingly building and using their own network infrastructure, the importance of Internet hubs for most digital companies remains high. Within the digital infrastructure, data centers act as depots where data is preferably stored and transmitted near strategic network traffic hubs. For this reason, the Frankfurt region[7] has become the largest centre for colocation data centers in the EU.

THE DEVELOPMENT OF THE DATA CENTER LANDSCAPE

The development of the data center landscape reflects the significant advances in information technology and the increasing demands on data processing and storage capacities. This evolution can be divided into various key phases:

1. Early phase (1950s-1960s): In the early years of computer technology, data centers were characterised by large mainframe computers whose use was mainly restricted to large companies and government institutions. These systems required considerable financial investment and specialised, climate-controlled premises.

2. Minicomputers and server rooms (1970s-1980s): The introduction of minicomputers marked the beginning of an era in which data centers became accessible to a broader user base. Companies established their own server rooms to centrally manage their IT processes, which enabled a more diversified application of computing centres across different sectors.

[7] The definition of Frankfurt as a data center location includes the greater Frankfurt area („metropolitan region“).

3. The internet and the beginning of the cloud (1990s-2000s): The spread of the internet led to an exponential increase in data volumes and thus increased the requirements for data processing and storage. This period was characterised by the emergence of colocation data centers, which offered corporate customers rental space for servers, initially mainly in large network hubs and international financial centres. The establishment of regional centres expanded accessibility for SMEs and other organisations. Towards the end of this phase, the introduction of cloud services began, which laid the foundation for the further development of data processing and storage outside of traditional facilities.

4. Cloud computing and virtualisation (2000s-2010s): The establishment of cloud computing fundamentally transformed the data center landscape. The ability to rent computing power and storage space flexibly and on demand led to significant cost savings and greater scalability. Virtualisation and automation further improved the efficiency of resource utilisation. With the rise of digital and social media in the 2010s, the demand for colocation data center space grew significantly, with cloud and media companies now generating much of this demand. This development led to a trend towards renting entire server halls, data centers or developing their own hyperscale data centers.

5. Hyperscale and edge computing (2010s-today): Large technology companies began to set up hyperscale data centers in order to meet the growing demand for cloud services. Parallel to this, edge computing is gaining importance by reducing latency and bringing data processing closer to the end user, which is particularly important for applications in the Internet of Things (IoT), autonomous vehicles and other real-time applications.

Investment activity in the area of new computing centres has increased significantly in Europe and especially in Germany. This development is partly due to the need to improve the provision of low-latency cloud services while meeting data sovereignty requirements. More and more companies are either legally obliged or prefer to store and process data within the European Union or their own country. As a result, hyperscale data centers are experiencing a wide geographical spread across Europe. For many of these facilities, it is a challenge to minimize the time to market and acquire wholesale space or power shells. Germany, which has a leading role in data sovereignty, has been quick to attract hyperscale companies, particularly in Frankfurt am Main. Frankfurt's strategic importance as a financial hub, the high density of consumers and companies and the advantages of low latency times for fast data transfer are decisive factors for the choice of location in order to promote further growth.

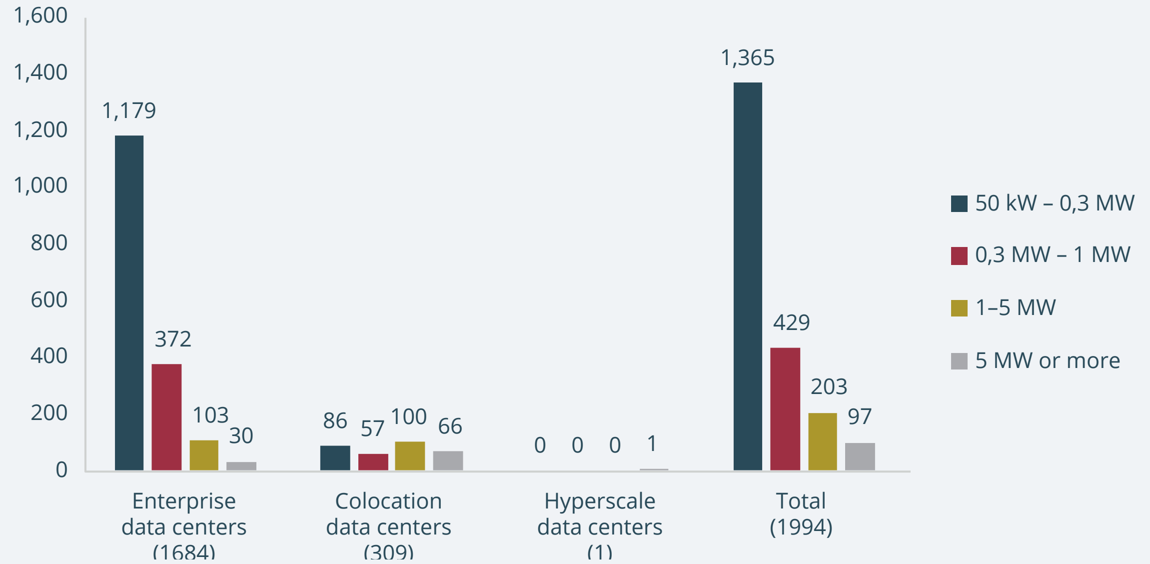
The vast majority of investments in German data centers in recent years can be attributed directly or indirectly to the growth of a relatively small number of hyperscale customers. With the increasing importance of artificial intelligence, additional significant investments can be expected in the coming years.

THE LANDSCAPE IN FIGURES

At the beginning of 2024, the number of enterprise data centers clearly outweighs colocation and hyperscale data centers, with around 1,700 enterprise data centers with a capacity of at least 50 kW. However, it should be noted that in most sectors, only companies with more than 4,500 employees exceed this 50 kW limit if they have their own data center. Exceptions to this are the financial and IT sectors, in which companies with more than 100 employees, as well as public authorities and educational institutions with 500 employees or more, already exceed the 50 kW limit. Against this background, it can be concluded that most of the 11,000 organisations in Germany with more than 250 employees do not have data centers that exceed this value. These findings are based on average values of enterprise data centers from an international database, which were applied to demographic aspects of the German corporate landscape.

This analysis does not take into account the specific computing centre capacities of higher education institutions and research institutes such as Fraunhofer-Gesellschaft, Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Centre), Max-Planck-Gesellschaft and Forschungszentrum Jülich (Jülich Research Centre). These institutions maintain some of the most advanced computing centres in Germany, which support complex scientific, technical and academic research projects. The data centers examined show a clear diversity in size; in addition to numerous smaller facilities, there are also larger data centers with capacities of 5MW or more, with colocation data centers playing an important role for a large number of customers. This development also highlights a trend towards consolidating distributed enterprise data centers into colocation facilities in order to benefit from the efficiency, automation, connectivity, security and business continuity of these facilities.

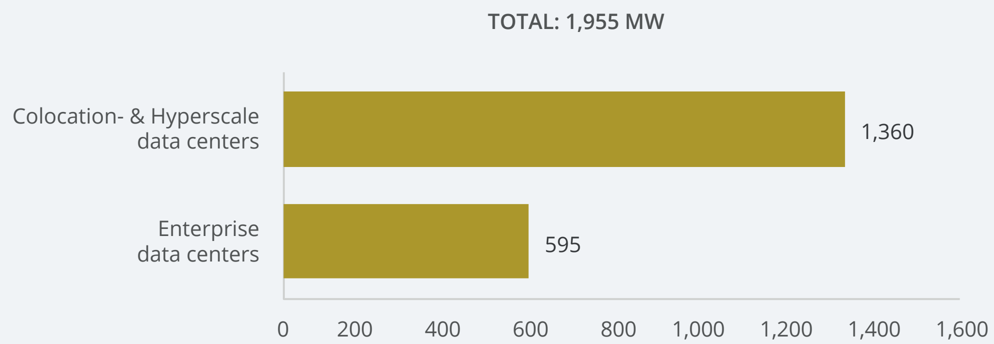
FIGURE 2: Data centers in Germany by type and IT power (50 kW or more), as at 1 January 2024



Source: Database for colocation & hyperscale data centers, 2024; Database for enterprise data centers, 2024

Although enterprise data centers dominate in terms of numbers, colocation and hyperscale data centers are already responsible for the majority of IT performance. On average, these facilities are more modern and offer higher performance (kW) per rack compared to enterprise data centers. As many colocation data centers in Germany also serve international markets, this segment is particularly well developed.

FIGURE 3: IT Power (MW) in Germany by type, as at 1 January 2024



Source: Database for colocation & hyperscale data centers, 2024; Database for enterprise data centers, 2024

IMPORTANT TRENDS AND DEVELOPMENTS

The development of the data center landscape in Germany is shaped by a number of key trends that can be divided into categories such as market developments, technological advances in data center infrastructures and regulatory frameworks. Key market trends are characterised by the ongoing digitalisation of the global and local economy and include topics such as cloud migration, the importance of edge computing and the influence of artificial intelligence (AI). High-density computing, sustainable innovations and dealing with energy requirements and restrictions are among the foremost technological developments. At a regulatory level, the German Energy Efficiency Act (Energieeffizienz-Gesetz, EnEfG) and the European Energy Efficiency Directive (EED) require companies to implement energy-efficient solutions and processes. The use of renewable energies, innovative cooling technologies and energy-efficient hardware are the focus here in order to reduce CO2 emissions. Local regulations, such as the „ Rechenzentrenkonzept – Aktualisierung des Gewerbeflächenentwicklungsprogramms (Data center concept – update of the commercial space development programme)"[8], which was published on 9 June 2022 by the Frankfurt City Council, place additional demands on the data center industry.

MARKET TREND 1: DIGITALISATION

The digital transformation is having a significant impact on the way communication, media consumption and business operations take place worldwide. The automation of processes through digital technologies increases efficiency and productivity both in companies and in the public sector. This accelerates research and development processes and leads to the emergence of new digital services, markets and business models. The resulting increase in data volumes requires expanded computing and storage capacities as well as improved connectivity solutions. Future innovations in areas such as AI, machine learning, quantum computing and efficiency technologies will continue to drive this development.

MARKET TREND 2: CLOUD AND EDGE

The introduction of cloud computing around two decades ago revolutionised the use of computing centres. The ability to flexibly rent computing power and storage space led to significant cost savings and greater scalability for companies. Virtualisation and automation enabled more efficient use of resources. The use of cloud services is now ubiquitous and is growing at a double-digit percentage rate every year.

The migration of customers to the cloud by independent software vendors (ISVs) continues, with a vision of a completely cloud-based future. At the same time, corporate IT environments are increasingly developing into hybrid architectures, some of which are located in various cloud models, others in enterprise or co-location data centers, with the latter being preferred due to their flexibility and improved connectivity.

The cloud industry's response to this development can be seen in the increasing decentralisation through hyperscalers, which are developing new clusters in regional centres. This enables customers to store and process data in the cloud within specific regions and at the same time fulfil data protection regulations, reduce latency times and lower network costs.

The development towards a decentralised infrastructure in the world of hyperscale data centers has a counterpart in the increasing importance of edge computing, which aims to move data processing closer to the end user. This development is of particular relevance for technologies such as the Internet of Things (IoT), supported by the progressive expansion of 5G technology, autonomous vehicles and other applications that require real-time data processing. Some of these requirements can be met by computing capacities and storage options directly on the end device itself. In other scenarios, however, local data processing and storage is required, -storage that takes place in close proximity to the end device, also known as the "edge". Small colocation data centers that are strategically distributed across the country and support these specific requirements offer a solution for this.

MARKET TREND 3: ARTIFICIAL INTELLIGENCE

The artificial intelligence (AI) market trend is characterised by a dynamic and rapid development that is driven by a variety of factors. This trend encompasses several key areas and reflects both technological advances and changing market requirements.

The scientific study of AI began more than five decades ago, with considerable investments totalling billions being made over the course of time to achieve decisive breakthroughs. However, for a long time there was a lack of sufficient computing capacity and data storage to develop effective AI applications, as well as a lack of scientific results that would enable the technology to be widely used.

Over the past two decades, the picture has changed fundamentally: advances in hardware, access to computing and storage capacity through cloud technologies and increased connectivity have favoured a fast and comprehensive flow of data. The availability of supercomputing has enabled companies to use machine learning to train

[8] https://www.stadtplanungsamt-frankfurt.de/steuerung_von_rechenzentren_22137.html (last accessed: 01/03/2024).

algorithms, which has led to significant changes in research and development (R&D) in various sectors such as the automotive industry, high-tech and pharmaceuticals. AI applications are also helping to optimise manufacturing processes, improve preventive maintenance and gradually increase operational efficiency, productivity and sustainability. Before the introduction of technologies such as ChatGPT[9] , the global AI market – including hardware, software and services – was already worth over 450 billion US dollars, with Europe accounting for around a quarter of this.

Both the public and private sectors are investing heavily in AI research and development, which is driving innovation in numerous application areas from digital patient records to the automotive industry. Advances in machine learning and deep learning, algorithms and neural networks have enabled the efficient processing of large amounts of data and the recognition of complex patterns, significantly increasing the performance of AI systems in image and speech recognition, natural language processing and predictive analytics. As a result, AI is increasingly being used in a wide range of industries, including but not limited, to healthcare, financial services, retail, manufacturing, traffic control, resource management and energy supply. Platforms and tools that facilitate access to AI technologies are becoming increasingly common. In addition, the integration of AI with other technologies such as the Internet of Things (IoT), blockchain and augmented reality (AR/VR) is fuelling the creation of new areas of application and innovation.

In the context of the increasing use of artificial intelligence (AI), the construction of data centers is expected to change. An increase in AI-specific data centers is predicted, particularly in locations with access to large quantities of inexpensive, renewable energy sources, such as in the Nordic countries. New hybrid, AI-enabled data center concepts are likely to to encourage further investment in this sector, led by hyperscale cloud providers who are aiming to closely integrate cloud solutions with AI. Colocation data center providers are also investing in new facilities capable of supporting high-density AI workloads. The combination of regional cloud expansion and the breakthrough of AI could result in a further significant growth spurt in the data center sector.

TECHNOLOGY TREND 1: HIGH-DENSITY DATA PROCESSING

The technology trend of high-density data processing addresses the increasing demands on data centers, network infrastructures and data processing systems in order to keep pace with the exponential growth of data volumes and the need for efficient, fast processing of this data. The use of advanced processor technologies and architectures such as multi-core CPUs, GPUs (Graphics Processing Units) and TPUs (Tensor Processing Units) enables higher computing power in a smaller space. These technologies support complex calculations and data analyses in real time. In view of the high density of computing power, energy requirements are also increasing.

As a result, there has been a continuous increase in the power available per rack. Current data centers offer an average of around 10 kW per rack; this range is constantly being expanded to include capacities for high-performance computing (HPC), i.e. for high-performance, high-density (HD) computers, which have a significantly higher energy requirement per rack. These units are optimised for demanding computing operations, such as those found in AI applications, and currently achieve outputs of up to 30 kW per rack.

With the ongoing development of AI, the transition to high-density data processing concepts is accelerating, with potential rack capacities of up to 100, 300 and even 500 kW. This development requires significant modifications to both the architectural design and the cooling systems of data centers. It is to be expected that certain segments will adapt to liquid cooling, sometimes in combination with conventional air cooling. One specific approach to liquid cooling is immersion cooling, which is likely to gain in importance in the future. The complete immersion of computing units promises high energy efficiency, but poses additional challenges in terms of weight management (especially in the case of raised floor constructions), process integration, mechanical design and the use of cooling systems.

The main focus of the project is on the compatibility of the server components, as well as support and warranty services for the server components concerned. Until widespread implementation, further solutions need to be developed and validated in order to enable cost-effective realisation. There are also physical modifications for data centers, which are reflected in a relative increase in the size of the technical rooms compared to the data processing area and a move away from point-to-point cabling in favour of structured cabling systems. If used appropriately, these adjustments can contribute to a reduction in power usage efficiency (PUE). In addition to the increased efficiency, the residual heat is characterised by a high quality (temperatures between 40 and 60 °C), which emphasises their relevance for reuse purposes.

Innovations in cooling technology, energy efficiency in processors and systems and the use of renewable energies are key to improving sustainability and reducing operating costs.

[9] For example: Artificial Intelligence (AI) Market Size, Growth, Report to 2032 (https://www.precedenceresearch.com).

TECHNOLOGY TREND 2: CHALLENGES IN THE ENERGY SECTOR AND SUSTAINABLE INNOVATION

Data centers are critical infrastructures in our increasingly digitalised world, but their operation is confronted with considerable energy consumption and the associated environmental impact. Data centers consume a significant proportion of the world's electricity, driven by the requirements for computing power, data storage and network infrastructure. A large proportion of energy consumption in data centers is used for cooling systems to ensure the optimal operating temperature of the hardware. Many older data centers have low energy efficiency, which leads to increased energy consumption and higher operating costs.

The challenge of securing sufficient access to electrical energy is becoming increasingly apparent in regions with a high density of data centers, such as Frankfurt am Main, or in cases where a hyperscaler is planning the construction of an extensive data center campus. This challenge is leading to increasing delays in the realisation of data center projects. In view of the potential impact on the power supply for other sectors of the economy and private households, concerns about energy consumption and, indirectly, the consumption of other resources by the data center sector are growing.

The efficiency of energy use in data centers is quantified by the Power Usage Effectiveness (PUE). This indicator determines the ratio of the total energy consumption of a data center to

the amount of energy used directly for the IT infrastructure, including servers, storage media and network components. Older and smaller data centers often have a less efficient PUE of around 2.0. In contrast, modern data centers with an average PUE of 1.3 for colocation data centers in Germany and 1.57 for company-owned data centers are significantly more efficient examples. In order to meet the new legal requirements of a PUE value of 1.2 in accordance with the Energy Efficiency Act (EnEfG) for new data centers from 2026, data center providers are driving innovation and focusing on more efficient concepts.

Furthermore, awareness is increasingly shifting towards overall energy consumption and the origin of energy from renewable sources. Aspects such as water consumption, sustainable construction methods and the harmonious integration of buildings into their surroundings are also gaining in importance. In line with the requirements of the EnEfG, more and more projects are being developed that aim to use waste heat from data centers to heat residential and office buildings.

In view of these developments, data center operators are increasingly investing in renewable energy sources, including solar, wind and hydropower, in order to meet their energy needs sustainably and reduce carbon dioxide emissions.

REGULATORY TREND 1: THE EUROPEAN ENERGY EFFICIENCY DIRECTIVE AND THE GERMAN ENERGY EFFICIENCY ACT

In September 2023, the new European Energy Efficiency Directive (EED) officially came into force, which plays a central role in realising the sustainability goals of the EU Green Deal. The amended directive is aimed in particular at the data center sector and obliges member states to require data centers within their jurisdiction to report on their environmental footprint. This measure is intended to provide a basis for the implementation of sustainability metrics, the identification of optimisation potential and the establishment of control mechanisms to ensure compliance with the guidelines.

From the following year, data centers in the European Union with an IT capacity of at least 500 kW – including colocation, hyperscale and enterprise data centers – will be required to report on indicators such as energy efficiency, the share of renewable energy, the reuse of waste heat and fresh water consumption. Data centers with a capacity of 1 MW or more are urged to adhere to the European Code of Conduct on Data Centre Energy Efficiency (EU DC CoC), a voluntary initiative that so far has been signed by over 500 European data centers.

The reporting data collected is fed into a database that serves as a basis for evaluating future requirements for the sustainability of data centers in the EU. The directive also requires data centers with a capacity of over 1 MW to carry out a cost-benefit analysis regarding the feasibility of reusing waste heat.

Some EU member states, particularly Germany, are implementing even stricter measures than those provided for in the directive. Also in September 2023, the German Bundestag passed the new Energy Efficiency Act (EnEfG), which specifically addresses data centers. This law stipulates that new data centers – regardless of whether they are colocation, hyperscale or enterprise centres – with a non-redundant IT capacity of at least 300 kW must achieve a maximum PUE value of 1.2 from July 2026. In addition, the targets for heat recovery must be quantified and the energy supply must be completely converted to renewable energies. Increasingly strict regulations also apply to existing data centers. As part of the reporting process, operators are obliged to store relevant data in the central energy efficiency register and other information on the waste heat platform.

REGULATORY TREND 2: REGIONAL REGULATION AND CHALLENGES

Before the focus of EU and national legislation on energy efficiency in data centers, it was primarily local initiatives that issued regulations for this sector. In June 2022, for example, the city of Frankfurt am Main presented the Frankfurt Master Plan for Data centers. This plan combines urban planning elements – in particular the approval of new data centers – with sustainability requirements that focus primarily on the PUE value and the use of waste heat for urban heating networks. In view of the comprehensive requirements established by the EnEfG and the "Municipal Heat Planning" programme, it is unlikely that many cities or federal states will follow this example. However, in view of the increasing network utilisation and the growth of data centers in other German cities, an increase in regional regulations in the context of municipal planning is to be expected, although this should not prevent the establishment of data centers.

Forecasts indicate that the demand for space and energy supply for data centers in Germany will continue. This growth will be further promoted by the digital strategy initiated by the German government, which is providing numerous impulses for digitalisation in public administration and the economy. Despite this progress, there is still considerable potential for digitalisation measures in these areas, for which a reliable and secure digital infrastructure is essential. Market reports and analyses indicate that the market for data centers in Germany will see strong growth in the coming years.

The German market for colocation data centers has undergone rapid development. Co-location data centers offer rack units, racks, server areas, rooms, halls or complete data centers for rent to individual users. This includes both retail and wholesale colocation, including purpose-built data centers („built-to-suit“ or „powered shell“). As of 1 January 2024, this study covered 264 existing colocation and hyperscale data centers with an IT capacity of 50 kW or more, with a further 34 facilities in planning or under construction. Due to many factors in the survey of small facilities the study estimated 46 facilities in the so-called long tail with an average data area of 100 m², which corresponds to 0.7 % of the market size In total, these facilities have almost 1.5 million square metres of space, of which 690,000 square metres are available as rentable data space, which is sufficient to house more than 300,000 server racks. A total of 1,349 megawatts are available to power these facilities, which corresponds to an average of 4.5 kW per rack.

TABLE 1: Sizing the German market for colocation & hyperscale data centers, as of 1 January 2024

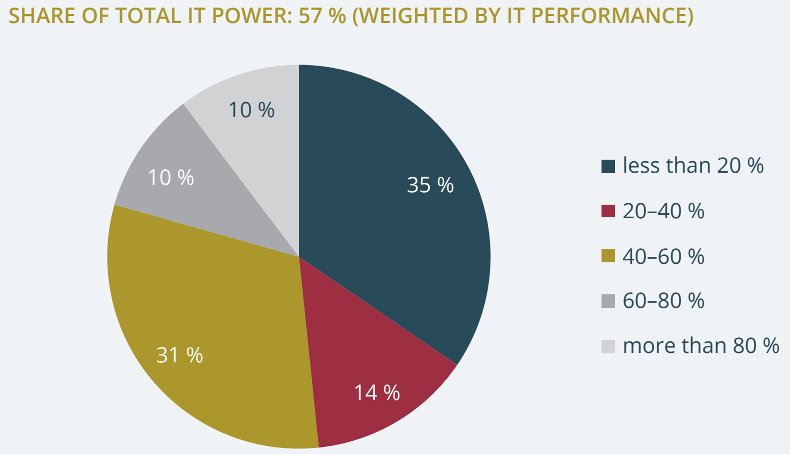
	2023	2024	WACHSTUM
Gross surface (in 1,000 sqm)	1,327	1,455	9.6 %
Net surface, data floor (in 1,000 sqm)	635	690	8.7 %
IT Power (MW)	1,202	1,349	12.2 %
Racks (000)	277	302	9.0 %
Data center facilities (#)	302	309	2.3 %
Colocation provider (#)	151	153	1.3 %

Source: Database for colocation & hyperscale data centers, 2024

The distribution of colocation data centers in Germany is not balanced, with almost two thirds of the available IT capacity concentrated in the Frankfurt am Main region in Hesse. Frankfurt is a significant international location for data centers and is one of the largest in the EU. It is part of the so-called FLAP-D markets (Frankfurt, London, Amsterdam, Paris and Dublin), which have dominated the international colocation data center landscape for years and act as central hubs for the European market. The data analysis revealed that around 57% of the total available data center space is international, while the remaining 43% serve the national market.

For the Data Center Impact Report Germany 2024, we conducted a survey among members of the German Datacenter Association and non-member data centers. The 29 participants in the survey represent 71% of the German colocation data center market, measured in terms of IT performance (MW).

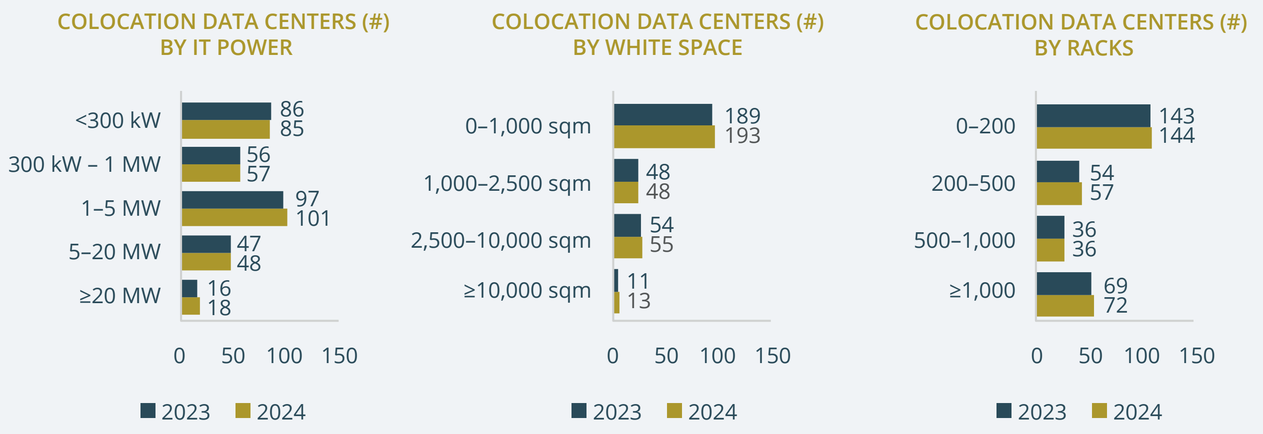
FIGURE 4: Question: What percentage of the (used) capacity in Germany is aimed for the international market?



Source: Survey of colocation data center operators, 2024 (N=29)

The study also took into account data centers with an IT capacity of just 50 kW, although most colocation data centers offer capacities of over 1 megawatt. The number of small colocation data centers is declining, as some companies (managed service providers or hosting companies that also offer co-location services) discontinue their colocation services or move their servers to other colocation data centers.

FIGURE 5-7: Colocation data centers by size (IT Power, white space, rack space), as at 1 January 2023, 1 January 2024



Source: Database for colocation & hyperscale data centers, 2024

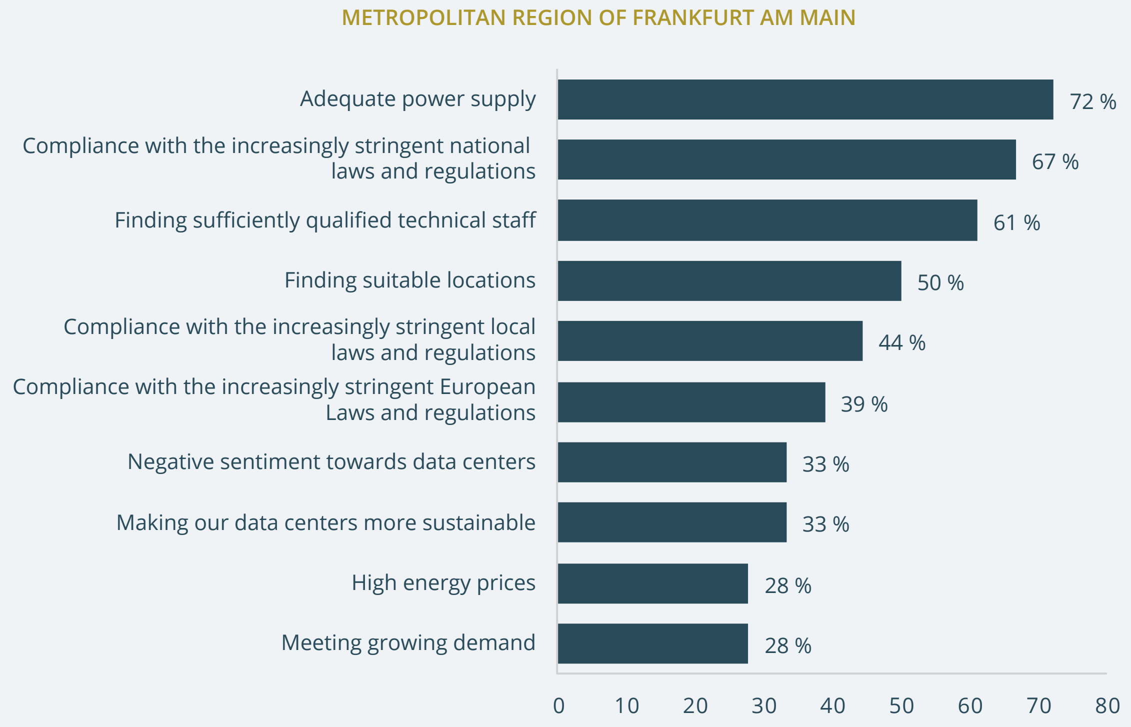
DRIVING FORCE AND OBSTACLES

A variety of market, technology and regulatory trends are driving change in the data center market. These trends generate different dynamics: While some of them stimulate strong growth in demand for colocation services, others pose significant challenges or cause significant changes in the colocation segment.

Digitalisation, the increasing use of cloud services and the integration of artificial intelligence are factors that are significantly accelerating the growth in demand for colocation. IT and telecommunication companies are expanding their data center infrastructures in order to develop and provide digital solutions. At the same time, shifting workloads to the cloud leads to a reduction in the capacity required in company-owned data centers. Companies facing the challenge of modernising outdated facilities are increasingly using colocation services for those workloads that have not yet been moved to the cloud. This is resulting in the growth of colocation data centers at all levels, with retail data centers growing particularly rapidly from enterprise demand and wholesale and build-to-suit providers to meet the needs of cloud providers who are increasingly relying on AI.

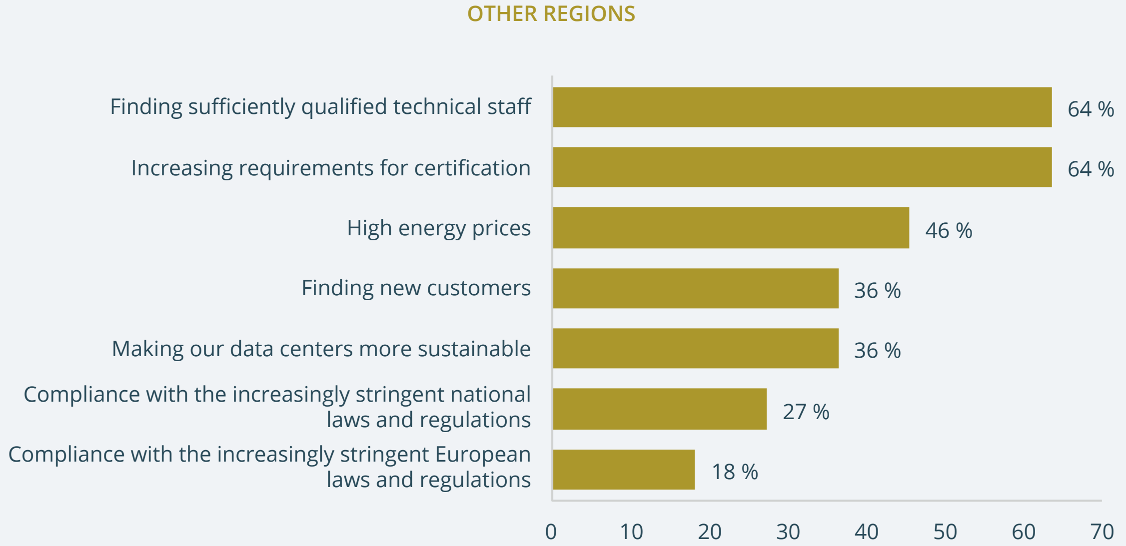
The main challenges to growth are regulatory requirements and energy restrictions, particularly in the Frankfurt region. Many data center operators identify the limited access to electricity (72%) and the challenges posed by German and European regulations (67%) as significant obstacles. In addition, the recruitment of qualified technical staff is seen as a challenge across the industry in order to keep pace with increasing customer demand.

FIGURE 8: Question: What are the biggest challenges for your company in the next three years? [Multiple answers, Frankfurt am Main metropolitan region, top 10 answers]



Source: Survey of colocation data center operators, 2024, colocation companies with facilities in the Frankfurt am Main metropolitan region (N=18)

FIGURE 9: Question: What are the biggest challenges for your company in the next three years? [Multiple answers, except Frankfurt am Main metropolitan region, top 7 answers]



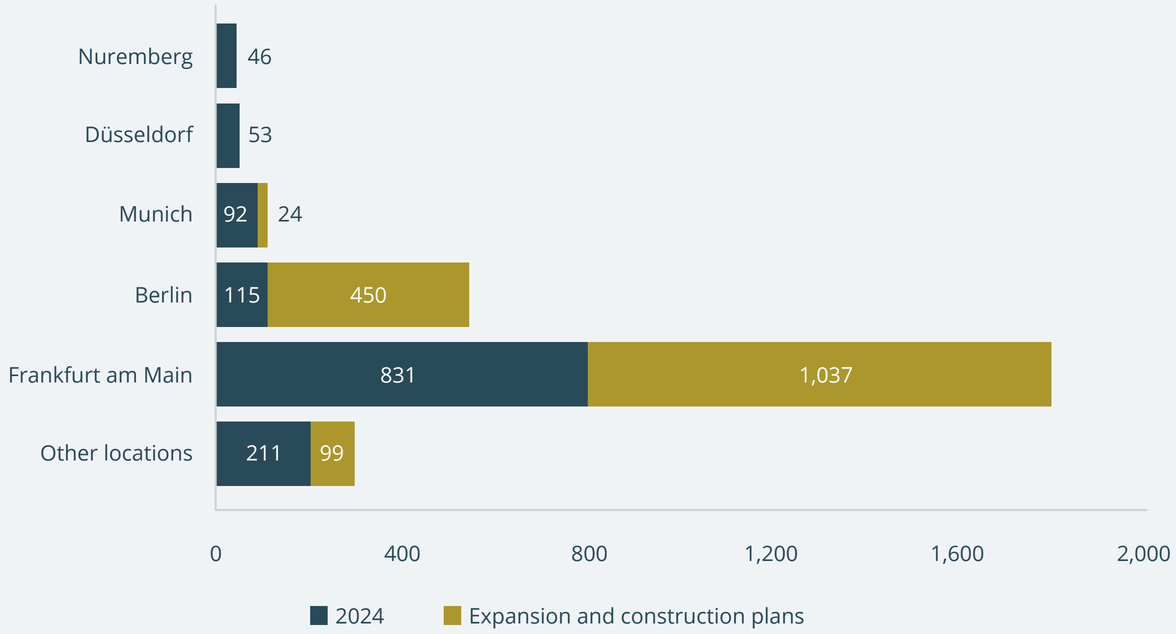
Source: Survey of colocation data center operators, 2024, colocation companies without locations in the Frankfurt am Main metropolitan region (N=11)

MARKET SIZE AND FORECAST

With regard to market size and forecasts, the focus is initially placed on IT capacity in megawatts (MW), which is an indicator of market capacity. Furthermore, investments in new data centers and the size of the colocation market in millions of euros are also considered.

The data center capacities added in 2023 show steady market growth, with a 12 % increase in available IT capacity. Plans for new data center projects with a total capacity of 1,610 MW have been identified, particularly in the Frankfurt region with plans to add more than one gigawatt. While growth in other German metropolitan regions is lower or not yet visible, Berlin is characterised by significant growth with almost 500 MW of planned hyperscale capacity for hyperscale customers.

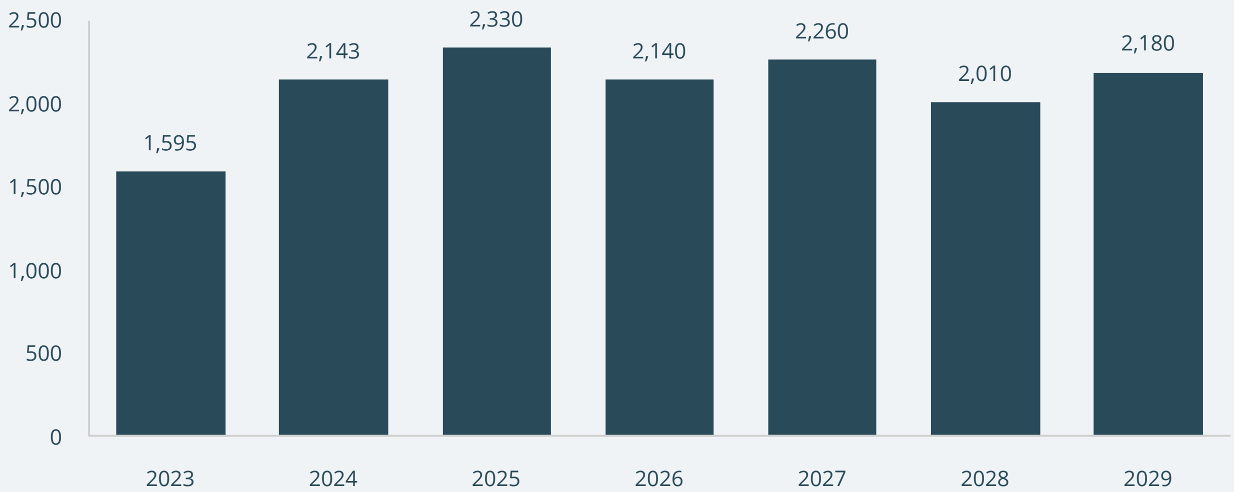
FIGURE 10: Construction and expansion plans by metropolitan region locations (MW IT capacity) as at 1 January 2024



Source: Database for colocation & hyperscale data centers, 2024

Investments in German data centers are showing a steady growth trend. In 2023, around 1.6 billion euros were invested in the construction of new data centers, with the forecast that investments will exceed 2 billion euros annually in the coming years. It is based on a conservative growth model that assumes additional, but not exponential, growth through AI in order to take into account the challenges posed by limited access to energy and potential construction delays.[10]

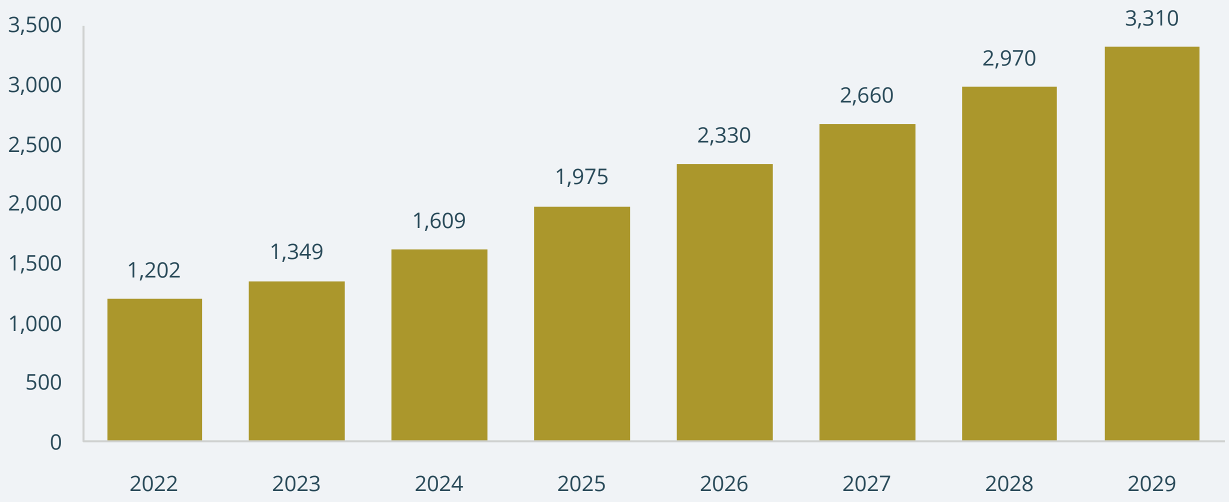
FIGURE 11: Investments in data centers (€ million), colocation and hyperscale, forecast 2023 – 2029



[10] In its classification on page 9, the German Datacenter Association contrasts this forecast with an investment forecast that quantifies the anticipated growth in IT capacity with market values for construction costs for the expanded data center, estimated average base unit prices and an assumed average land area efficiency.

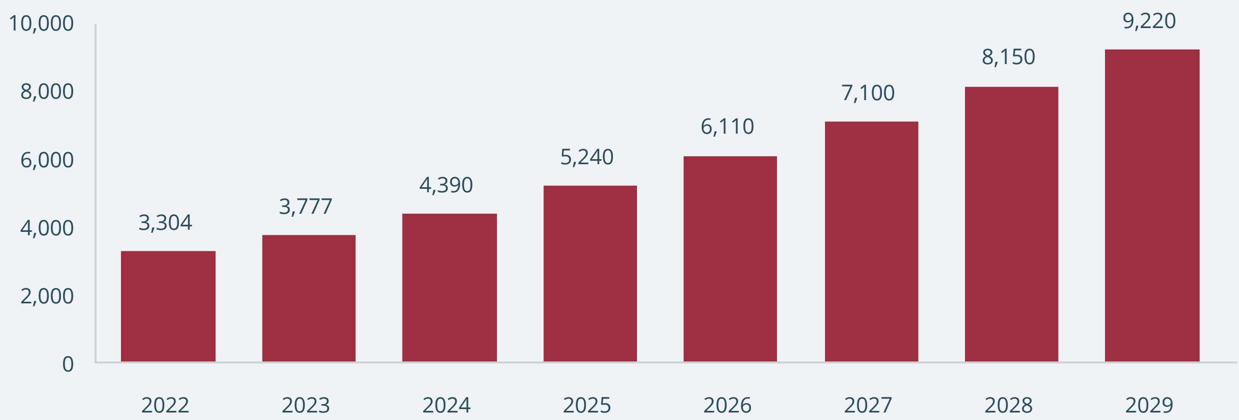
These investments will have a direct impact on the German data center landscape. Taking into account the annual increase in IT capacity, the market is expected to more than double to over 3.3 gigawatts within the next five years, with average annual growth in available IT capacity of 15.6 % between 2023 and 2029.

FIGURE 12: Colocation data center market size (MW) and forecast (%), 2022 – 2029 (compound annual growth rate 23-29: 15.6 %)



Market revenues are expected to grow even faster, driven by inflationary effects on electricity prices, building materials and wages, as well as by a shift in the sales structure in favour of built-to-suit offerings, resulting in lower sales per square metre.

FIGURE 13: Colocation revenue (€ million), 2022 – 2029 (compound annual growth rate 24-29: 16.0%)

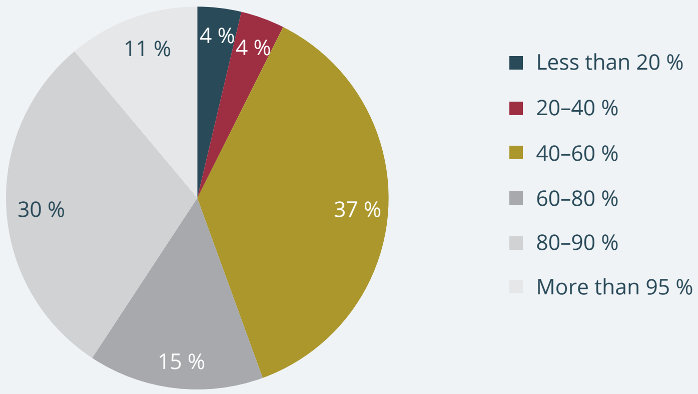


GROWTH TRENDS

Over the past year, it has been reported several times that the supply of data center space is limited. However, a survey of German colocation data centers provides differentiated insights. One segment of operators (11% of respondents) faces significant challenges with occupancy rates over 95 %. This contrasts with the finding that almost half of the operators have a utilisation rate of less than 60%. Taking into account the size of the company, the average overall utilisation is 70%, which implies that 30% of the colocation space is still available for new customers.

FIGURE 14: Question: What is the approximate current occupancy rate?

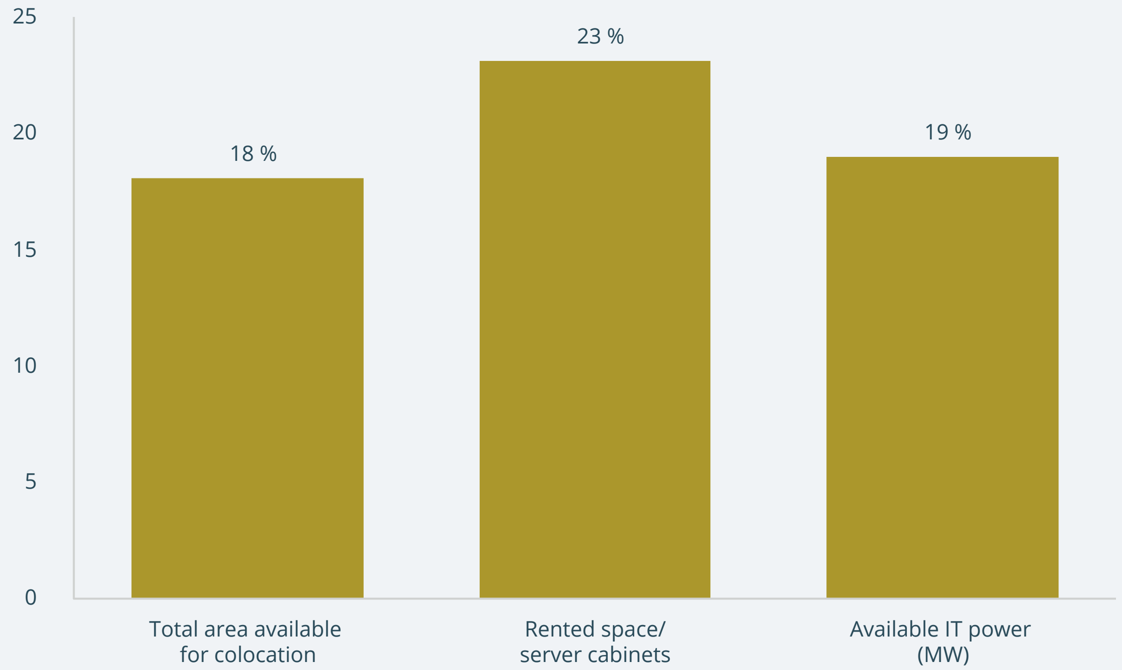
TOTAL MARKET: 70 % (WEIGHTED BY IT POWER)



Source: Survey of colocation data center operators, 2024 (N=29)

Despite the current availability of capacity, it should be noted that these spaces are likely to be occupied quickly. With regard to the forecast for 2024, respondents expect demand for rented data center space or data racks to increase by 23%. This indicates that the current supply could be fully utilised within a year. Expectations regarding the expansion of total space and IT power capacity are 18% and 19% respectively, which falls short of demand.

FIGURE 15: Question: By what percentage do you expect your company to grow or shrink in 2024?

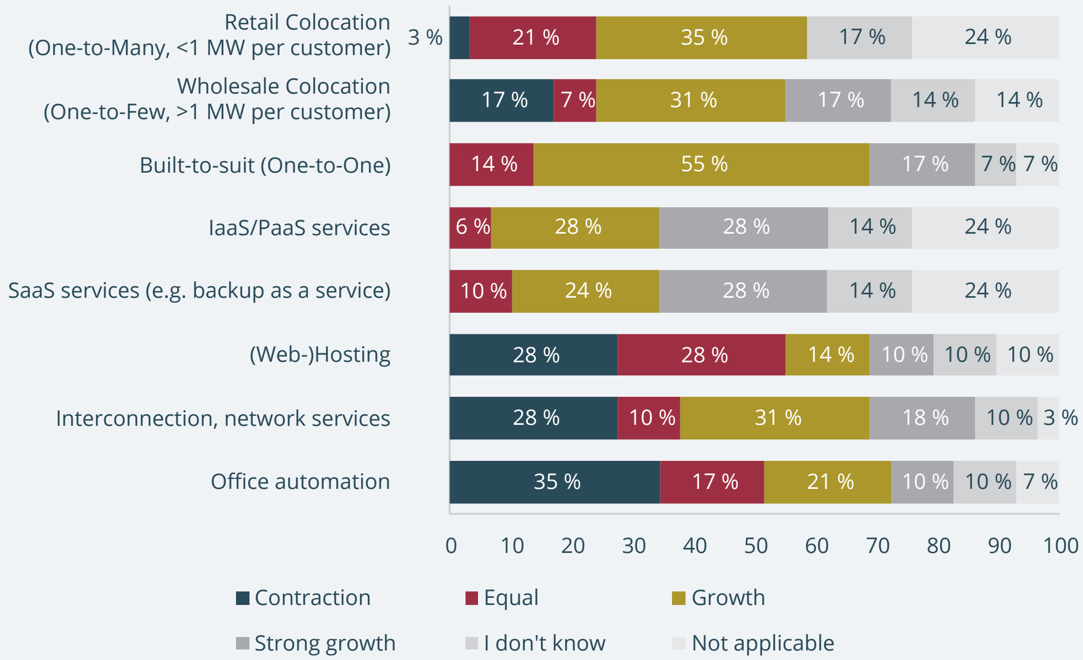


Source: Survey of colocation data center operators, 2024 (N=29)

The business models of data centers vary. Colocation is the core offering for most multi-tenant data centers. The majority of the data centers surveyed in this study offer both dedicated and wholesale co-location solutions, with some also offering customised solutions (build-to-suit). Continuous, and in some cases, even strong growth is expected in all of these segments, particularly in the area of customised solutions. The combination of colocation services with network solutions, such as fibre optic connections, cloud-on-ramps and interconnections, is on the rise. Given the trend towards decentralising data processing in order to bring data closer to the end user (edge computing), these network services are rapidly gaining in importance. Data centers that specialise in interconnection are often experiencing strong growth, whereas operators that offer traditional connectivity solutions, have rather conservative growth expectations.

With regard to medium-sized and smaller domestic data centers, it should be noted that the development in the area of colocation services is not always linear. Similar to other sectors, organisations that have outsourced their server infrastructures to colocation facilities are increasingly looking to move their workloads to cloud environments. This results in a reduction in the need for physical rack space over time. As a strategic response to this development, data center operators are increasingly diversifying their offering towards Infrastructure-as-a-Service (IaaS) and Platform-as-a-Service (PaaS). In contrast, the forecasts for traditional IT services, such as office automation and web hosting, tend to be more cautious and conservative.

FIGURE 16: Question: In which of the following areas do you expect revenue to increase or decrease over the next three years?

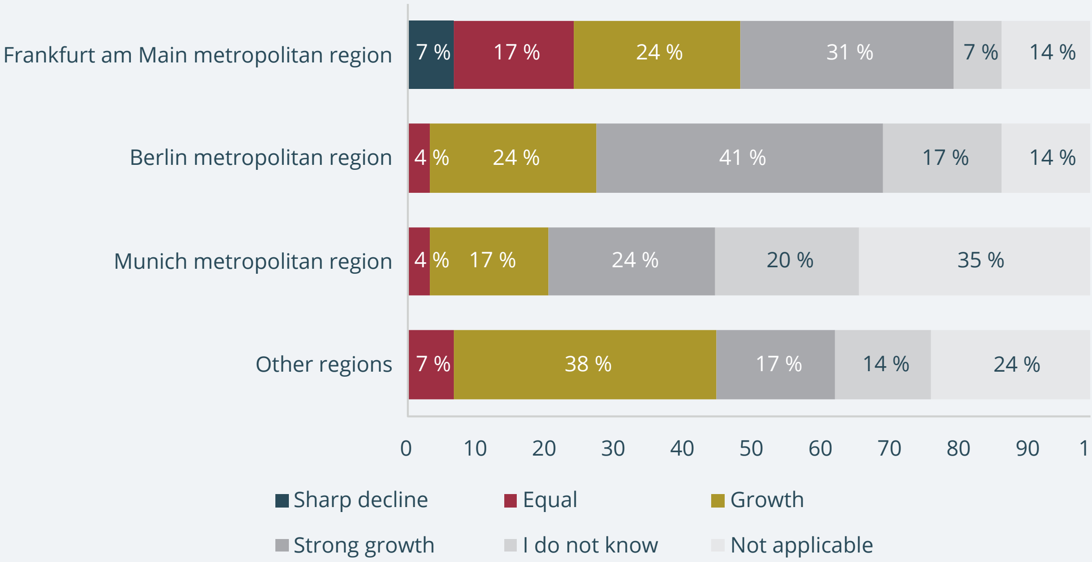


Source: Survey of colocation data center operators, 2024 (N=29)

GROWTH BY REGIONS

The regional context shows that colocation data centers in the Frankfurt am Main area are primarily geared towards the international market, but also serve a substantial domestic market. Berlin is developing into a second central data center location in Germany, with a particular focus on supplying the metropolitan region and northern and central Eastern Europe. In both cities operators of colocation data centers expect growth, in some cases even strong growth. Optimism also prevails among data center operators in Munich, although the construction volume is not reaching the level of Berlin and Frankfurt. Those surveyed who are active in this region are nevertheless positive.

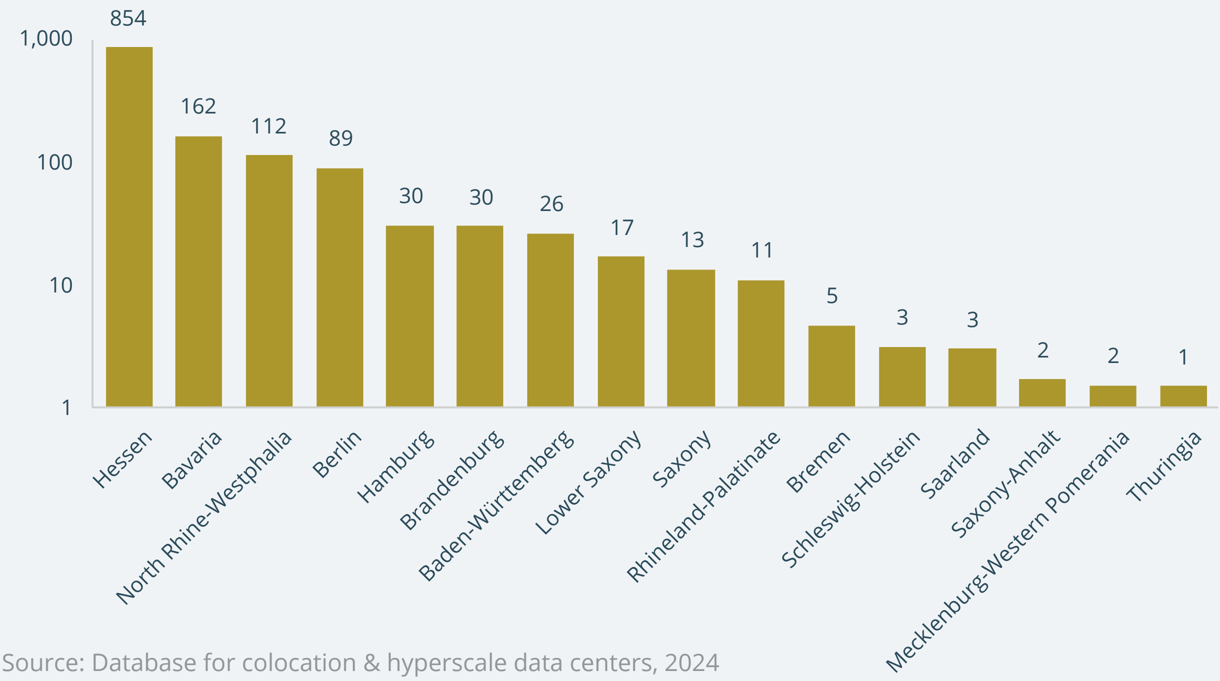
FIGURE 17: Question: In which of the following regions do you expect revenue growth or a decline in revenue in the next three years?



Source: Survey of colocation data center operators, 2024 (N=29)

Data centers in other German regions mainly focus on the national, often even the local market. Their customer base typically includes regional IT service providers, local software companies, public institutions, small and medium-sized enterprises and locally based companies. Nevertheless, the service portfolio of these data centers are not uniform; some focus exclusively on colocation and connectivity offerings, while others provide a broader range of services including hosting, cloud services or office automation. Some data centers specialise in certain regions, while others aim to build a national network.

FIGURE 18: IT Power (MW) in Germany by federal state, as at 1 January 2024 (logarithmic scale)

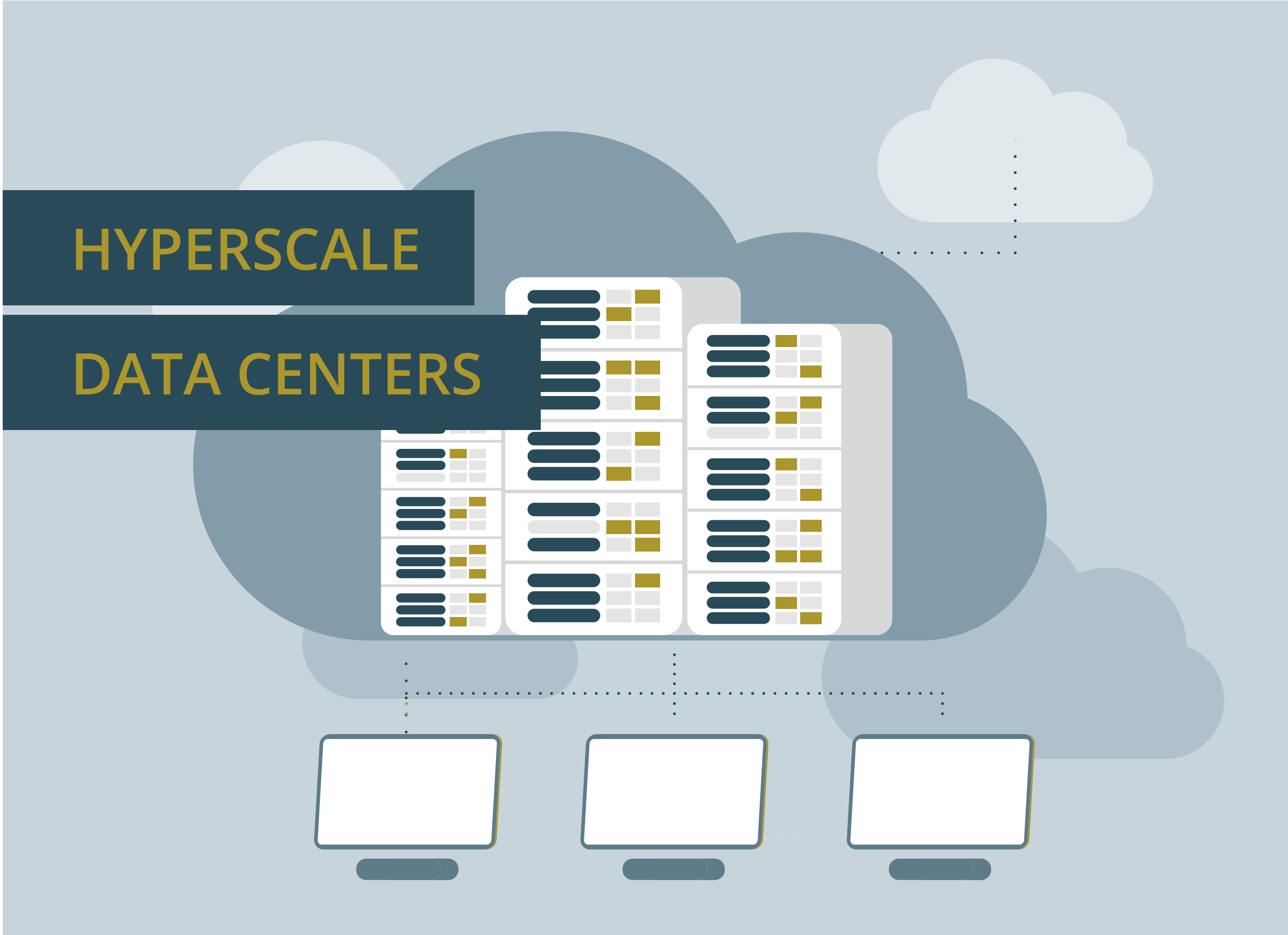


Source: Database for colocation & hyperscale data centers, 2024

The growth potential for domestic data centers differs from that of internationally oriented institutions. Local demand has increased, partly due to the Covid pandemic, as many German companies required a robust digital infrastructure to enable remote and home office working. Analysts predict a continued increase in demand for local data center services, driven by investment in digital resources and increased regulatory requirements in the areas of sustainability and energy efficiency.

According to the current regulations of the Energy Efficiency Act, large data centers with a non-redundant nominal connected load of over 300 kW are addressed. It is to be expected that smaller enterprise data centers will also have to meet comparable sustainability and energy efficiency requirements in future, including the transparent presentation and active reduction of their Scope 2 and Scope 3 emissions. This could result in an increased tendency for smaller companies to outsource their IT infrastructure to colocation providers.

HYPERSCALE DATA CENTERS



The analysis of the hyperscale market is limited to the consideration of data centers and data center areas that were built specifically for and owned by well-known hyperscale cloud providers such as Alibaba, Apple, AWS, Google, Meta, Microsoft (Azure), Oracle, IBM and Tencent. According to this criteria, there is only one hyperscale data center in Germany, the Google data center in Hanau near Frankfurt, which was inaugurated in October 2023.

The strategy of the hyperscale cloud providers listed with regard to the development and construction of their infrastructure varies from region to region. In the United States, the proportion of self-developed and built data centers is around 70%, while the remaining 30% is leased in order to shorten the time to market, especially in regions where approval procedures are more complex. In Europe, the ratio is more balanced. Hyperscale providers have built significant facilities in Europe, particularly in the Nordic countries, the Benelux countries, the UK and Ireland, but in other countries, such as Germany, they rely more heavily on rental solutions.

When expanding their cloud regions, hyperscale providers rent large facilities, often two, but usually three per city, for redundancy purposes. Service providers in this segment include companies such as NTT, Digital Realty (formerly Interxion) and Equinix.

The demand for large-scale, high-performance data centers and complete campuses is increasing, prompting established market leaders to diversify their hyperscale data center offerings and attracting new providers to the market that specialise in customised solutions (built-to-suit) for hyperscalers, including CloudHQ, Goodman, Stack Infrastructure, Vantage Data Centers and Virtus Data Centres. This also opens up opportunities for local providers who are familiar with the specific local authorisation requirements and regulations.

It is expected that these projects will be responsible for at least 75% of all new construction plans for data centers. The number of colocation data centers with a capacity of more than 20 MW will increase from 18 to around 40 or even 50 by 2030.

ENTERPRISE DATA CENTERS

Enterprise data centers, although less frequently mentioned in the media due to the high level of investment in colocation and hyperscale data centers, play a key role in the data center landscape.

This category includes a variety of operators, including government agencies, universities, hospitals, banks and other financial services providers, manufacturing companies, and telecoms and IT firms. Many of these organisations maintain a mixed data center infrastructure that includes both in-house facilities and colocation services, as well as cloud services and other managed and hosted services from third-party providers.

Physically, enterprise data centers are similar to co-location facilities in that they house the same equipment and must meet power, cooling and security requirements. On average, however, they tend to be smaller in size, with many facilities under 300 kW, which often results in lower efficiency levels compared to larger colocation and hyperscale data centers. The smaller size leads to fewer economies of scale, resulting in higher staffing requirements per square metre. In addition, less specialised staff are often used, with many employees covering a wide range of tasks and spending a significant proportion of their working time outside the data center as part of a broader IT remit.

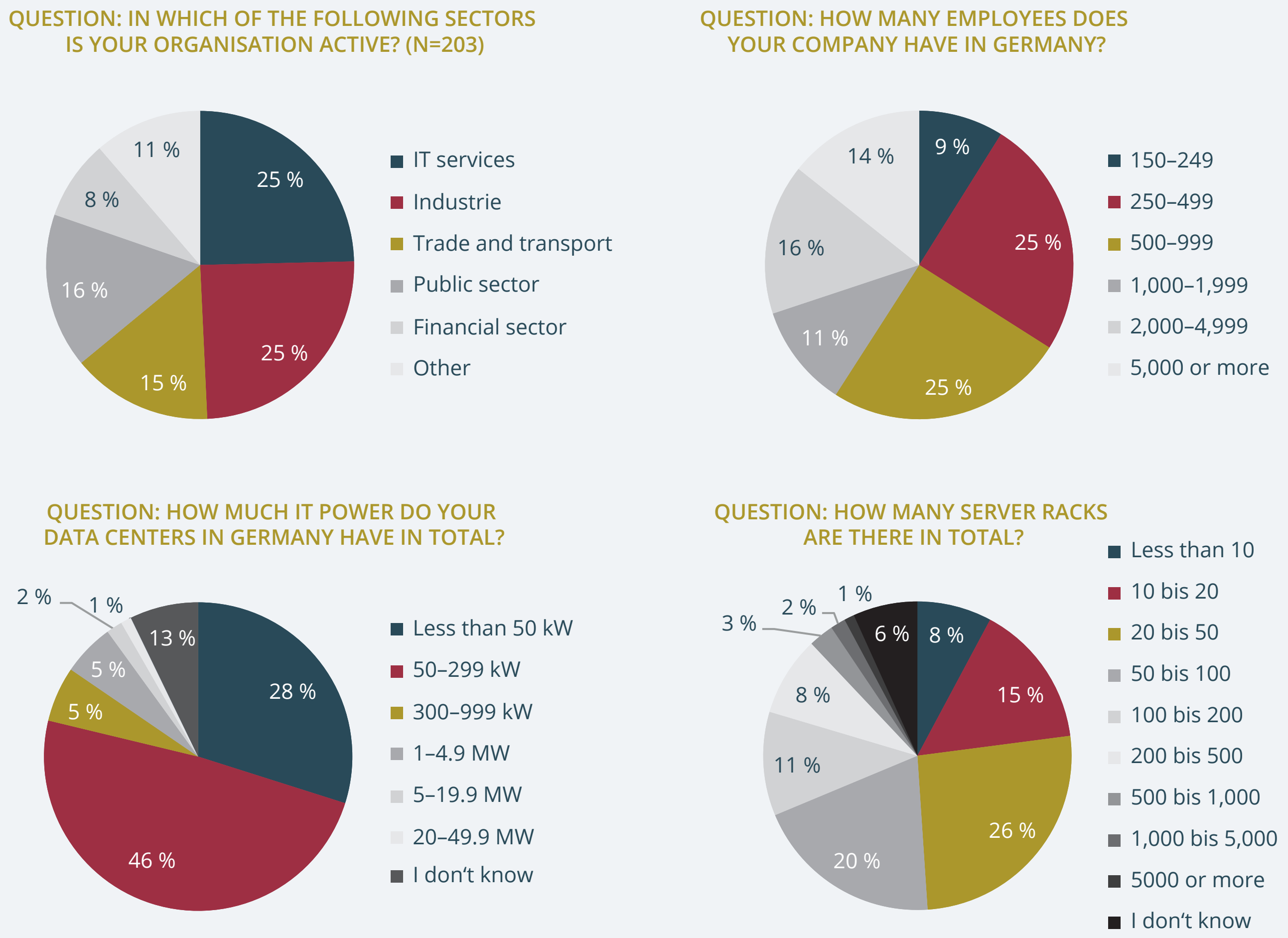
SURVEY

To gain in-depth insights into the dynamics of German enterprise data centers, a survey was conducted among decision-makers from 203 German enterprise data centers operating in companies with at least 150 employees. A quarter of the participants came from the IT services industry, while the rest came from various areas of the public sector and the corporate market.

Most of the data centers surveyed fell into the 50 to 299 kW performance category and had fewer than 100 racks.

The following analysis presents the results in terms of growth and challenges, while the following sections focus on employment, skills and sustainability.

FIGURE 19-22: Characteristics of the survey sample: sector, number of employees, installed IT Power, rack space

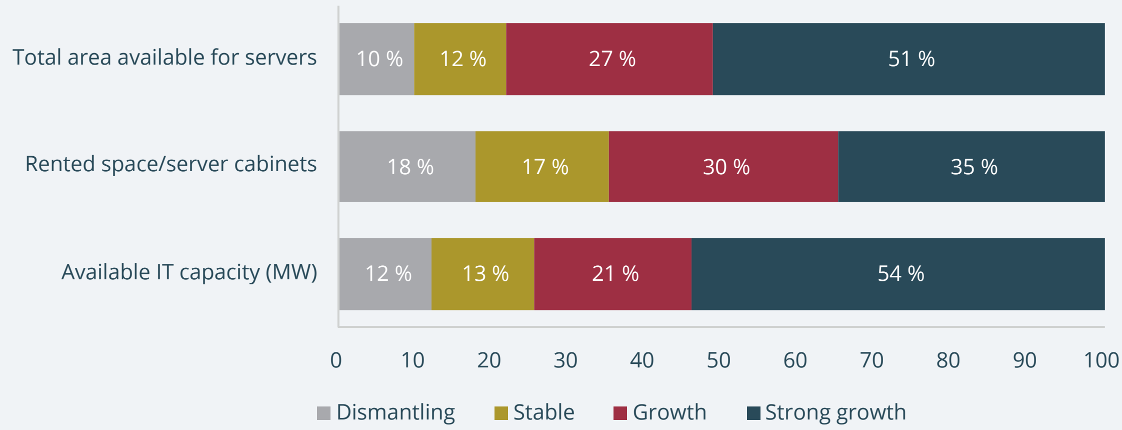


Source: Survey of companies that operate their own (enterprise) data center, 2024 (N=203)

BUILD OR BUY

The decision between building in-house data centers and sourcing from third-party providers has changed significantly over the past ten years. An increased shift of workloads to the cloud has been observed, with many companies pursuing a „cloud-first" or „cloud-only" strategy. The analysis of the survey results indicates a continuation, but also a partial reversal of this trend. 64% of respondents expect to rent more data center space in the future, whereby one third are even forecasting strong growth. At the same time, an increase in on-premise facilities is expected, which could increase further in 2024. Although a shift of workloads back from the cloud is being observed, this does not appear to be the only explanation. Rather, cloud providers are expected to grow by 15 to 30 % annually, driven by increasing digital investments after a pandemic-related decline and optimism about the AI boom.

FIGURE 23: Question: Do you expect your data center operation to grow or shrink in 2024?



Source: Survey of companies that operate their own (enterprise) data center, 2024 (N=203)

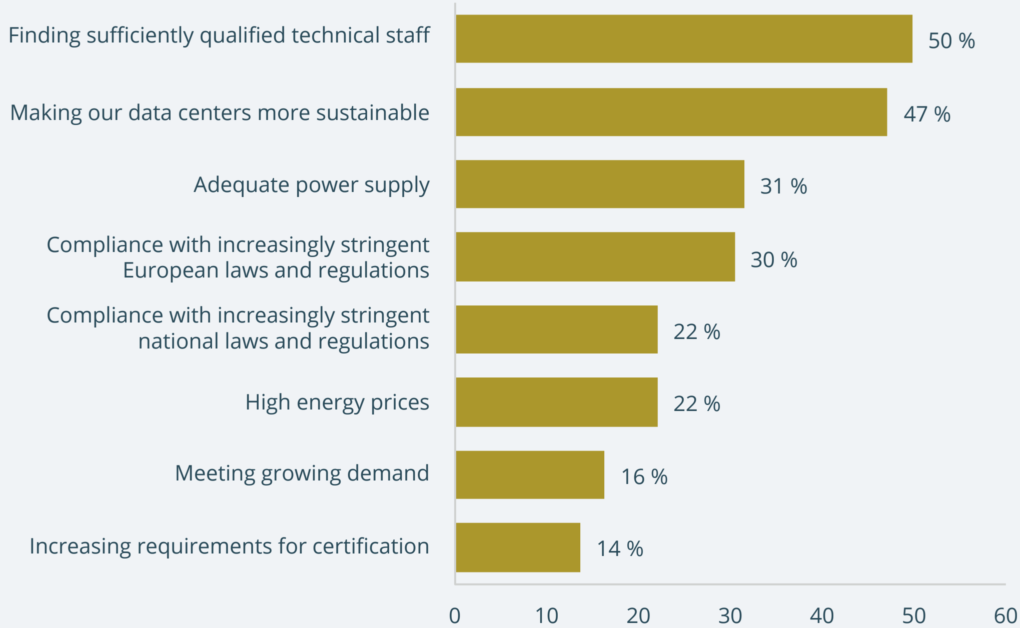
CHALLENGES

Enterprise data centers face similar challenges to colocation and hyperscale data centers, particularly with regard to the recruitment of technical staff. Technical skills are needed and there is competition for specialists between different sectors.

Sustainability is highlighted by every second enterprise data center as an important topic for the next three years. The realisation that smaller data centers are lagging behind larger data centers in terms of efficiency and sustainability, as well as increasing public and official interest in energy consumption and increasing efficiency in data centers, is leading to an increased thematic debate among decision-makers. In addition, optimising the energy efficiency of outdated systems offers significant potential for reducing electricity costs.

There is a desire for more sustainability, even if the stricter regulations only come into effect above a certain size. Although there is a strong interest in greater sustainability, stricter regulations currently only apply above a certain size. Enterprise data centers with more than 300 kW of non-redundant power are subject to the same legal requirements as colocation data centers. The simpler requirements for colocation data centers to meet the changed requirements could encourage an additional trend from enterprise to colocation data centers.

FIGURE 24: Question: What are the biggest challenges for your company in the next three years? [Multiple answers, top 8 answers]



Source: Survey of companies that operate their own (enterprise) data center, 2024 (N=203)

SOCIO-ECONOMIC EFFECTS OF DATA CENTERS IN GERMANY

Data centers have a significant socio-economic impact on the German market. As previously mentioned, the primary contribution of data centers is the provision of a robust digital infrastructure, which is essential for the development of the digital economy. Digitalisation increases the efficiency and competitiveness of companies, enables the government and the public to establish new value-added services and promotes the emergence of new innovations and business models. These „downstream effects“ are crucial for the modernisation of the German economy and the achievement of ambitious climate targets.

A focused consideration of data centers and their „upstream“ value chain makes it possible to quantify their influences by means of an economic impact analysis.

Data centers generate billions of euros in domestic and foreign investment, create thousands of jobs in data centers and their supplier industries, and generate new tax revenues that support local communities. This chapter describes both the impact and some of the challenges in terms of technical skills and attracting skilled labour.

ECONOMIC EFFECTS

Various studies have determined the economic effects of data centers. The methodology used here reflects the contribution to the German economy. The effects are measured on three levels:

- Direct impact: Includes the value of the goods and services produced by the company or the direct contribution to gross domestic product (GDP), including sales revenue minus the cost of intermediate input; employment in centres of economic activity.
- Indirect impacts: Refers to the GDP contribution of the company's supply chain, including the production of goods and services necessary for the operation of data centers, such as materials, utilities and business services as well as employment in the value chain.
- Induced effects: Concerns the consumer spending of employees of data centers and their suppliers, for example on food, housing or leisure activities, as well as related employment in the local economy.

Various studies consider the construction industry as part of the direct effects. However, the allocation to the indirect effect is methodologically more precise. After all, the establishment of data centers leads to additional direct, indirect and induced tax revenues, which is taken into account in the economic impact model used.

METHODOLOGY

A methodological approach based on the combination of data from a specific database for data centers and surveys was chosen to create the model of the economic impact of data centers in Germany. The initial aim was to determine the direct impact on gross domestic product (GDP) and employment. To this end, turnover and employment data, some of which came from a colocation survey and some from direct surveys and operator information, was extrapolated and checked against comparative values from international studies. The focus was primarily on hyperscale and colocation data centers, with enterprise data centers being considered to a lesser extent: The employment figures for enterprise data centers were not included in the calculation of the GDP contribution in this study; similarly, tax data was also not quantified due to a lack of availability from the surveys.

To calculate the indirect (GDP contribution of the supply chain) and induced effects (consumer spending by direct and indirect employees), the recognised method of national input/output statistics[11] was used to create a model of the economic impact. The IT services sector served as the basis, with specific adjustments based on other studies on the spending behaviour of data centers, such as above-average investment in construction in high-growth markets, to increase the precision of the model.

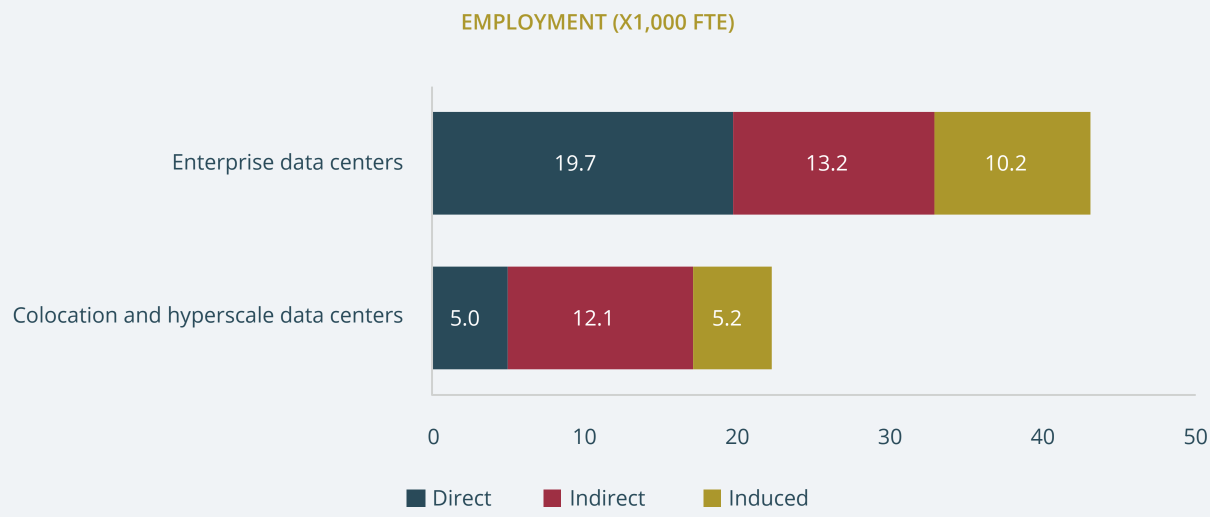
EMPLOYMENT

The analysis distinguishes between employment effects in colocation and hyperscale data centers on the one hand and enterprise data centers on the other. Due to their size and specialisation, colocation and hyperscale data centers have efficiency advantages and employ staff in both the back office and the front office. Enterprise data centers, on the other hand, which do not sell data center services, usually rely on company resources for back-office functions.

It was found that colocation and hyperscale data centers employ around 5,000 full-time equivalents (excluding subcontractors), while enterprise data centers employ almost 20,000 full-time equivalents (FTEs). The employment figures for the colocation and hyperscale market are based on data extrapolations from international surveys. When determining employment in enterprise and IT data centers, a focused perspective was adopted to ensure that only jobs directly associated with the construction and operation of the data center are taken into account. These include physical security personnel, building technicians, IT technicians, site managers and project management. While some analyses include additional IT staff responsible for managing IT systems in the facilities, these were not included in this study as they are considered users and not direct employees of the data center. However, IT employees who perform specific tasks within enterprise data centers were included in the full-time equivalent calculations.

[11] https://stats.oecd.org/Index.aspx?DataSetCode=IOTS_2021 (last accessed: 01/03/2024).

FIGURE 25: Economic impact of data centers in Germany, employment effects, 2024



Source: Survey of colocation data center operators, 2024 (N=29); survey of companies that operate their own (enterprise) data center, 2024 (N=203); extrapolation by Pb7 Research

INDIRECT AND INDUCED EMPLOYMENT EFFECTS

The supply chain structures of data centers comprise a multi-layered network of companies ranging from construction and installation companies and suppliers of electrical equipment to security service providers, energy supply companies and various corporate service providers. As a result of the significant investments in data center infrastructure, these suppliers make considerable investments in order to be able to provide the products and services in demand. A significant proportion of these activities take place in Germany, including the renting and furnishing of temporary office space for project employees, the purchase of raw materials, products and materials and the provision of temporary accommodation for construction and assembly workers.

The presence of colocation and hyperscale data centers generates over 12,000 full-time jobs in Germany, while enterprise and IT computing centres create a further 13,000 jobs, which corresponds to a total of 25,300 jobs. In view of the extensive investments, particularly in the construction of new facilities in the colocation and hyperscale segment, the proportion of indirect jobs in this sector is disproportionately high compared to the corporate market and most other sectors of the economy.

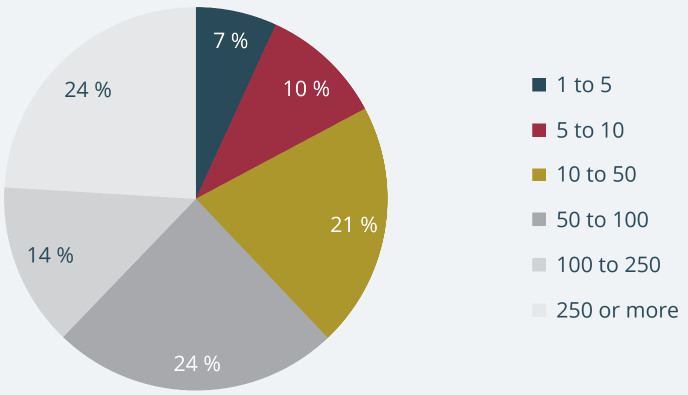
Furthermore, employment in this sector leads to significant secondary economic effects, as employees spend part of their income within the German economy, often in local contexts, on services such as food, housing and leisure activities. This consumption supports an additional 15,400 full-time jobs in Germany.

EMPLOYMENT WITHIN A DATA CENTER

Given the shortage of qualified technical staff, colocation/hyperscale data centers not only need permanent employees, but also a significant contingent of temporary workers. According to a survey, the average data center employs between 50 and 100 people, but also uses a smaller group of contractors. As the size of the data center operator increases, the proportion of contractors tends to increase as well. The commissioning of a large, new data center using only local staff is a considerable challenge. Once these new facilities move into operational mode, they rely heavily on the services of contractors. Over time, data center operators aim to replace contractors as far as possible with permanent, preferably local, specialists. In addition to around 5,000 permanent employees, more than 1,600 external workers are currently employed.

FIGURE 26: Question: How many employees work in your company (data center)? N.B. If colocation is your main activity, you can count all employees. If this is NOT your main activity, count only the employees who work in the data center organisation. – Own employees (FTE)

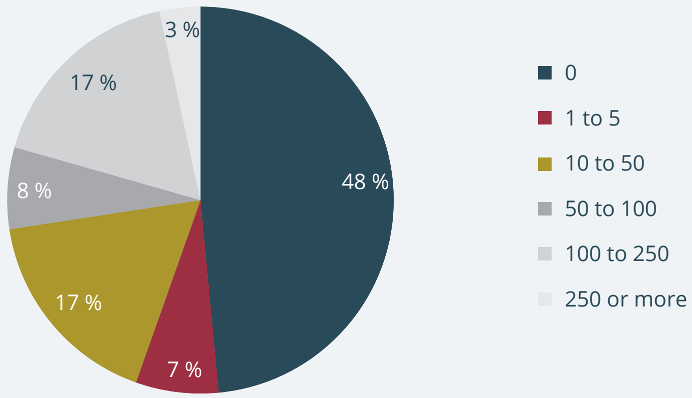
TOTAL FULL-TIME EQUIVALENTS: 5,000 (EXTRAPOLATION)



Source: Survey of colocation data center operators, 2024 (N=29)

FIGURE 27: Question: How many employees work in your company (data center)? Note: If colocation is your main activity, you can count all employees. If this is NOT your main activity, only count the employees who work in the data center organisation. – Hired employees (FTE)

TOTAL FULL-TIME EQUIVALENTS: 1,629



Source: Survey of colocation data center operators, 2024 (N=29)

EMPLOYMENT ROLES AND OPPORTUNITIES

In this study, a survey was used to develop a differentiated model that depicts the creation of jobs in different functions within data centers. When modelling the distribution of jobs, the size of the company was integrated as a variable in order to achieve greater precision in the quantification of jobs beyond the average percentages of the survey results. In particular, data centers are characterised by a high demand for specialist technical personnel who are required for the operational running of the facilities. This includes the monitoring and maintenance of cooling systems and other critical infrastructures to ensure operational continuity, as well as the preparation of the facilities for accepting new customers.

IT technicians play a central role in installation and maintenance at hardware level, including the replacement of components or the connection of cables. Data centers also have positions for site and project management, which are responsible for coordinating the wide range of operational activities. Colocation data centers also have dedicated departments for customer support as well as sales and marketing functions. Other administrative and management staff are required for internal organisation and administration, including an IT department that take care of internal system maintenance. Another relevant area of employment is physical security, which in many cases is handled by external service providers, as data center operators often do not include these tasks in their core business. Finally, the category of other jobs includes catering staff, who are primarily employed in larger data centers.

TABLE 2: Employment in data centers by area of activity, Germany, as at 1 January 2024

	COLOCATION AND HYPERSCALE DATA CENTERS		ENTERPRISE DATA CENTERS		TOTAL	
	%	FTE (incl. hired employees)	%	FTE (incl. hired employees)	%	FTE (incl. hired employees)
Security	10	700	28	8,100	25	8,800
Building technician	31	2,000	20	5,800	22	7,900
IT technician	24	1,600	28	8,100	27	9,700
Project manager	9	600	11	3,200	11	3,800
Site manager	7	400	8	2,200	8	2,700
Customer service (Service Delivery Manager, Helpdesk)	3	200			1	200
Frontoffice (Sales and Marketing)	3	200			1	200
Backoffice (personnel, finance, administration, etc., except IT)	5	300			1	300
IT (own systems)	2	200			0	200
Other	6	400	6	1,700	6	2,100
In total	100	6,600	100	29,400	100	36,100

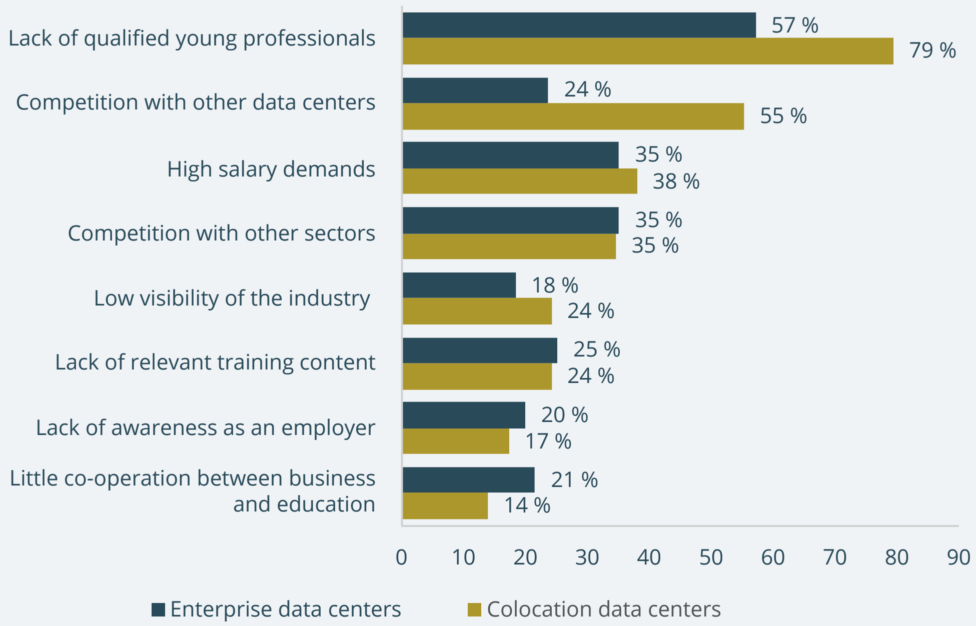
Source: Survey of colocation data center operators, 2024 (N=29); survey of companies that operate their own (enterprise) data center, 2024 (N=203); extrapolation by Pb7 Research

CHALLENGES ON THE LABOUR MARKET

As outlined in previous studies, access to specialised skills is one of the primary challenges for the data center sector. The demand for technical skills that are essential for the efficient operation of data centers is experiencing a cross-industry increase, particularly in the energy sector, which is also undergoing dynamic change. A key finding is that the current training system is not adequately tailored to the specific requirements of the data center sector. It is clear that academic and technical courses of study as well as dual training occupations are not sufficiently tailored to the requirements of data centers.

For example, the career opportunities in the data center industry with its extensive professional fields often remain uncovered. The industry should do more to raise awareness and advertise for young professionals. Data centers are in intense competition with each other for qualified specialists, especially in the colocation sector, which in turn leads to increased salary demands on the part of experienced technical employees. Interestingly, only a minority of respondents believe that there is insufficient cooperation between the industry and educational institutions, although this cooperation could be a key to improving the situation.

FIGURE 28: Question: In your opinion, what are the biggest obstacles in the search for new employees? [Multiple answers]



Source: Survey of colocation data center operators, 2024 (N=29);Survey of companies that operate their own (enterprise) data center, 2024 (N=203)

Recently, however, progress has been made in the co-operation between industry and educational institutions. Nevertheless, the shortage of skilled labour is affecting almost all areas with a strong trend towards a brain drain. In many areas of IT and air conditioning technology training, the practical relevance of training has improved noticeably, but the number of young professionals is still not sufficient to meet the demand for skilled workers in data centers and other competing sectors. This means that efforts must be made to increase interest in technical professions and attract more young people to the relevant training programmes. Initiatives to promote lateral entry and motivate young women to enter technical professions can be an integral part of a data center's diversity policy. A coherent approach to diversity policy offers the advantage of not only addressing the immediate need for lateral entrants, but also utilising the potential of diversity to achieve corporate goals at a structural level. It is therefore not just a question of finding enough employees, but also of utilising the advantages of diverse teams.

TABLE 3: Question: How many women are currently employed in technical and non-technical positions in your company (data center)?

	COLOCATION AND HYPERSCALE DATA CENTERS		ENTERPRISE DATA CENTERS		TOTAL	
	%	FTE (incl. hired employees)	%	FTE (incl. hired employees)	%	FTE (incl. hired employees)
Technical tasks	10	500	4	800	5	1,300
Other roles	26	400	20	1,900	20	2,300
In total	14	900	9	2,700	10	3,600

Source: Survey of colocation data center operators, 2024 (N=29); survey of companies that operate their own (enterprise) data center, 2024 (N=203); extrapolation by Pb7 Research

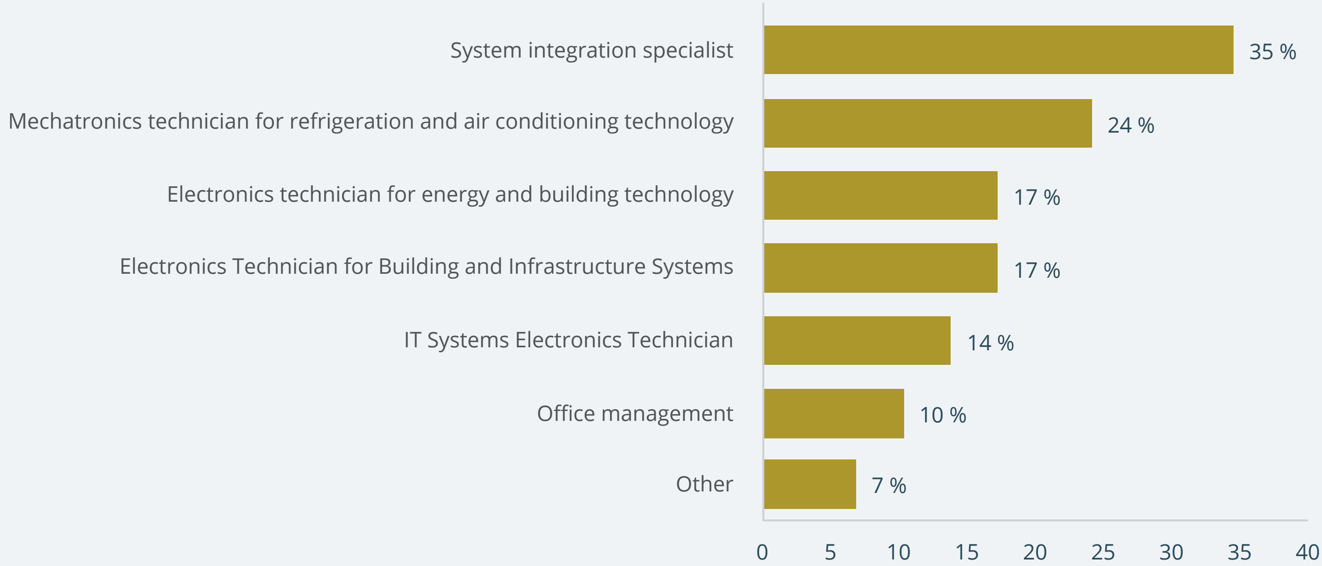
In terms of training measures, data centers play an active role by offering internal training programmes. The analysis of colocation and hyperscale data centers shows that there are approximately 250 trainees with a total workforce of 5,000 employees, plus 40 students in dual study programmes. The predominant fields of training include system integration and air conditioning technology, but the training programmes also extend to areas such as building and infrastructure systems, energy systems, IT systems and office management.

TABLE 4: Question: Do you provide training in your company?

	TOTAL
Number of trainees	250
Number of dual students	40

Source: Survey of colocation data center operators, 2024 (N=29); extrapolation by Pb7 Research

FIGURE 29: Question: In which of the following disciplines do you provide training? [Multiple answers]

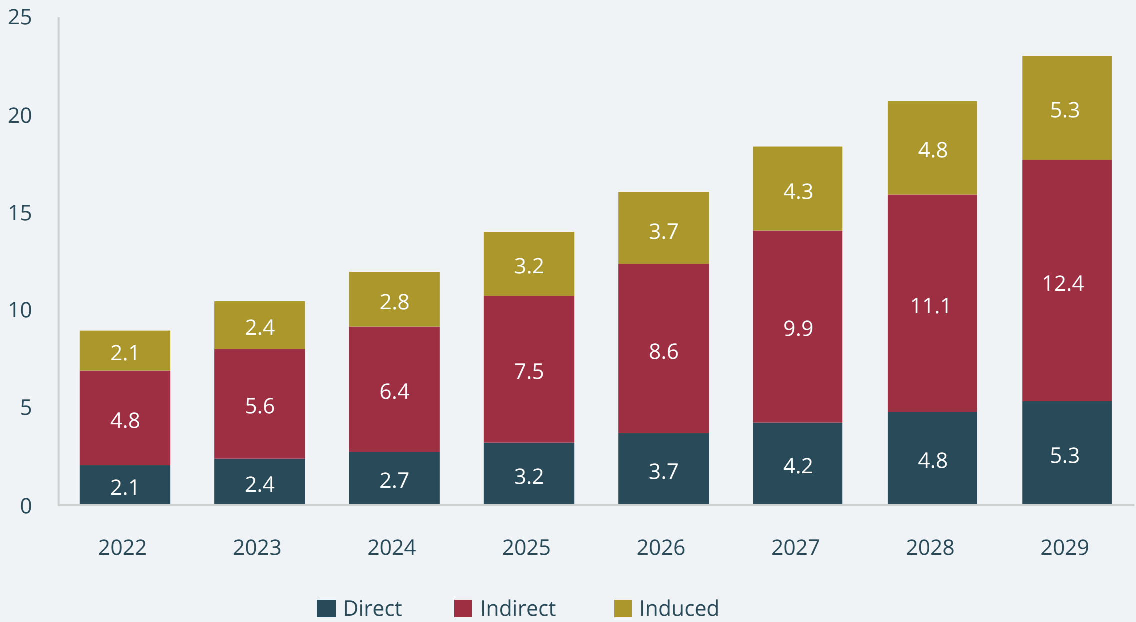


Source: Survey of colocation data center operators, 2024 (N=29)

CONTRIBUTION TO GROSS DOMESTIC PRODUCT

This analysis focuses on the economic value contribution generated specifically by colocation data centers. The economic significance of data centers that are owned by hyperscalers and companies is not considered separately in this study due to its complex interdependence with other sources of revenue.

FIGURE 30: Economic impact (EUR bn) of colocation data centers in Germany, contribution to GDP (average annual growth rate 24-29: 14%)



Based on the colocation market forecast developed for this study, colocation data centers will make a direct contribution of 2.4 billion euros to Germany's gross domestic product (GDP) in 2023. Furthermore, the contribution of the suppliers of these data centers to GDP is even more significant at 5.6 billion euros. In addition, an induced effect totalling a further 2.4 billion euros was identified. This brings the total contribution of colocation data centers to GDP in the year under review to 10.4 billion euros.

In view of the market growth presented in the forecast, it can be assumed that the total contribution of colocation data centers to GDP will increase to EUR 23 billion by 2029.

This development corresponds to an average annual growth rate of 14%. This data underlines the significant economic role that colocation data centers play within the German economy and highlights their contribution to increasing economic growth.

SUSTAINABILITY

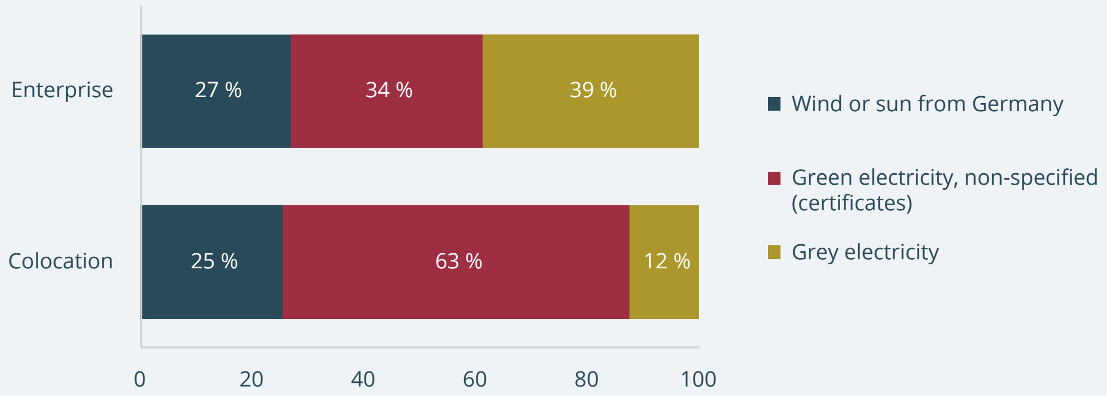
Data centers not only make an important contribution on a social and economic level, but are also characterised by their ecological footprint. On a positive note, data centers have almost completely switched to electric energy and are leading the way in procuring renewable energy, outperforming many other industries in terms of sustainability. Nevertheless data centers are confronted with a considerable responsibility due to their high electricity and, in some cases, water consumption and their constant growth.

The „Sustainability“ chapter focuses on analysing how data centers fulfil this responsibility in the areas of electricity consumption, efficiency enhancement and heat recovery.

CURRENT

Colocation and hyperscale computing centres in Germany in particular are characterised by a rapid transition to the use of green electricity. The industry is benefiting from its intrinsic electrification, which gives it a decisive advantage over other sectors with high energy requirements that are only just beginning to electrify. According to current data, colocation data centers obtain 88% of their electricity from green energy contracts, making the data center sector more advanced in its use of green energy than other industries, including enterprise data centers, which report that 61% of their electricity consumption comes from renewable sources. This data illustrates the sector’s commitment to sustainability, but also shows that additional measures are needed to further optimise power consumption and improve the climate balance.

FIGURE 31: Question: From which sources do you obtain the energy used in your data center(s)? [Weighted by IT Power]



Source: Survey of colocation data center operators, 2024 (N=29); survey of companies that operate their own (enterprise) data center, 2024 (N=203)

GREEN ELECTRICITY CONTRACTS

In the context of procuring electricity from renewable sources, it can be observed that a proportion of the contractually agreed electricity usually comes from renewable energy sources. However, this depends largely on the respective energy provider and the specific contractual constellation. Green certificates, which are often purchased from renewable energy plants such as Norwegian hydropower plants, play an important role here. Paradoxically, this system means that certain consumers in Norway are categorised on paper as users of conventional energy sources, even though they actually only use local renewable energy. German electricity from renewable energies.

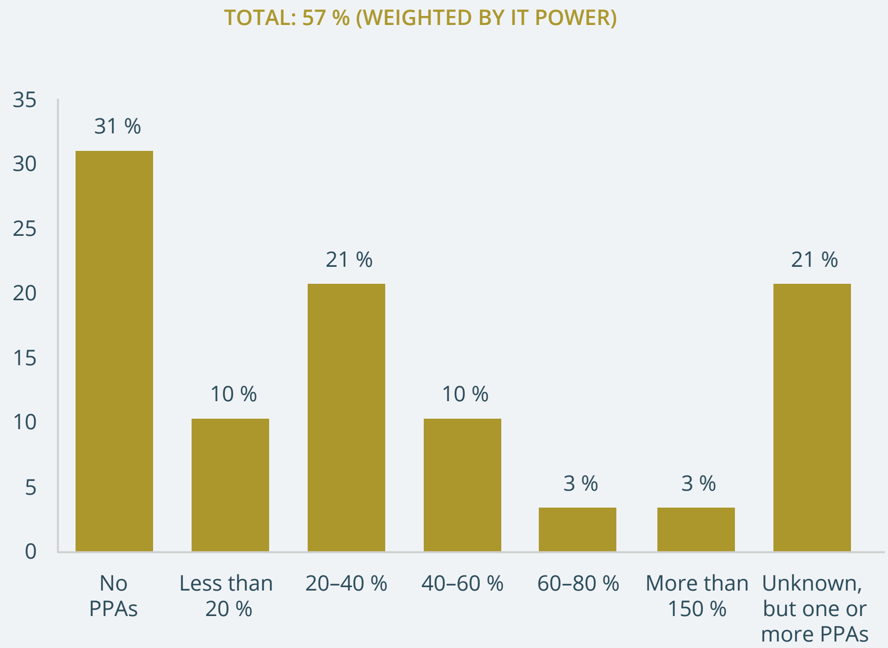
A central aspect of the discussion is therefore the promotion of local production and consumption of electricity from renewable sources. Energy suppliers that commit to supplying electricity from renewable energy sources within Germany or from other regional wind and solar plants are obliged to produce in line with their supply commitments. The purchase of local renewable energies ensures that energy suppliers invest in the expansion of these resources and thus make a more effective contribution to the sustainability of the electricity supply. According to GDA members and enterprise data centers, they already obtain around a quarter of their electricity from local renewable sources, with the aim of increasing this proportion further.

ELECTRICITY FROM RENEWABLE ENERGIES THROUGH PPA

Power purchase agreements (PPAs) offer a strategic opportunity to improve access to renewable energy. Under a PPA, a customer – in this case a data center – undertakes to purchase electricity directly from a renewable energy project, such as a wind or solar farm, over a longer period of time and receives a reduced electricity price in return.

Although it may appear that these agreements are merely buying up green energy capacities, it should be noted that many of these investments would not be realisable without the financial security provided by PPAs. The contractual commitment of large customers is essential in order to accelerate the realisation of these projects.

FIGURE 32: Question: If you have concluded Power Purchase Agreements (PPAs) with solar and/or wind providers, to what percentage do they cover your energy requirements?



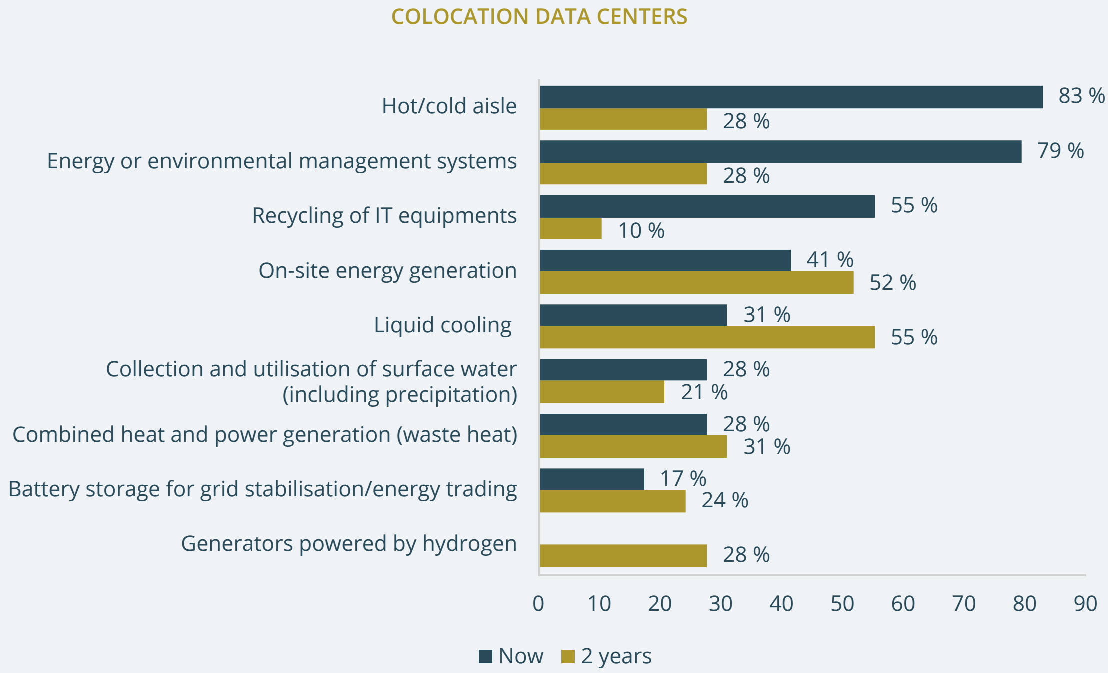
Source: Survey of colocation data center operators, 2024 (N=29)

The analysis of power procurement strategies in the German colocation and hyperscale data center sector reveals that power purchase agreements (PPAs) are responsible for 57% of total energy requirements. This high proportion is primarily the result of the commitment of a small group of the largest users, who cover a considerable proportion of their energy requirements through PPAs. It can be observed that an increasing number of data centers are pursuing the goal of fully covering their energy requirements with PPAs, with some hyperscale operators aiming for 100% coverage.

ON-SITE ELECTRICITY GENERATION

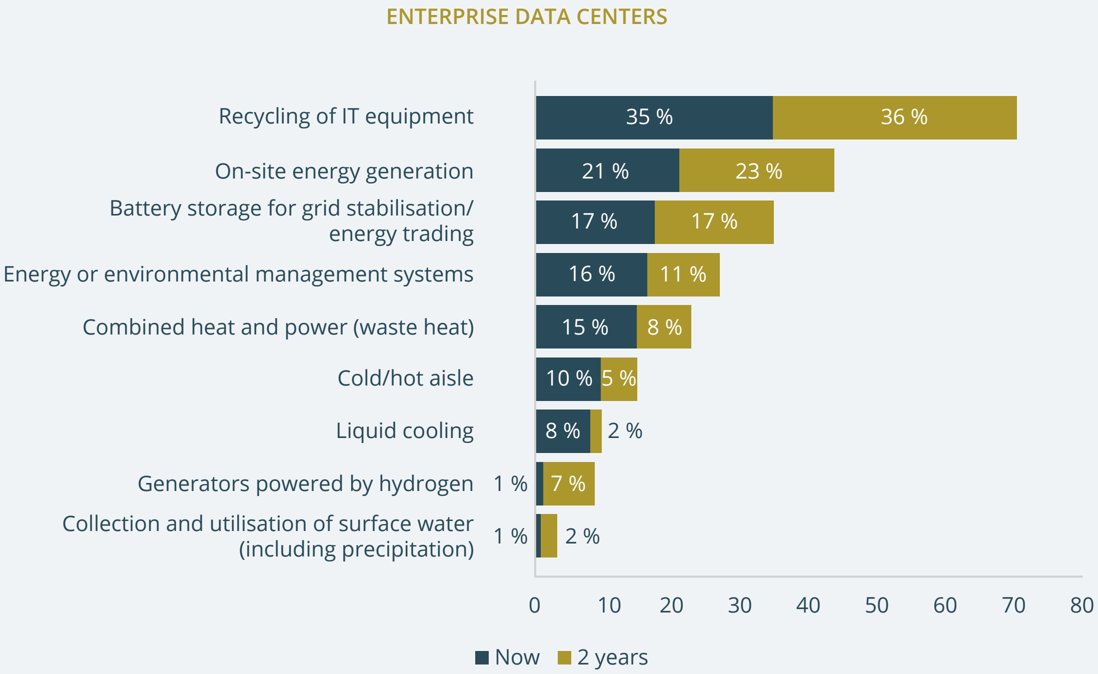
While local power generation certainly offers potential for data centers, operators often face challenges that make implementation difficult. In particular, building regulations and the limited space available, often in city centre locations, restrict the options for installing systems for local energy generation. For the majority of data centers, the integration of solar panels may seem like an obvious solution, but restrictive building regulations and the limited availability of suitable space – both on rooftops and on surrounding land areas – may prevent the practical use of such systems. In addition, for some locations, it may be possible to utilise wind energy or other sustainable energy sources, but here too, construction and spatial restrictions often present a significant obstacle. Despite these restrictions, more than 40% of colocation data centers have implemented measures for local power generation, while a further 52% are starting to implement or expand such systems. The corporate sector also shows that around one in five data centers is investing in technologies for local energy generation or already operates active systems. However, the limited options due to building regulations and a lack of space, particularly in densely built-up urban areas, require a creative and innovative approach to planning and implementing local power generation projects in order to sustainably cover the energy requirements of data centers.

FIGURE 33: Question A: Which of the following sustainability measures are you already implementing in your data center(s)? [Question B: Which of the following sustainability measures are on your agenda for the next 2 years? [Multiple answers]



Source: Survey of colocation data center operators, 2024 (N=29)

FIGURE 34: Question A: Which of the following sustainable initiatives do you already have in operation? [Multiple answers] Question B: Which of the following sustainable initiatives are on your agenda for the next 2 years? [Multiple answers]



Source: Survey of enterprise data centers (N=203)

DEMAND MANAGEMENT

The purchase of green electricity differs significantly from its actual utilisation, which is heavily dependent on the availability of renewable energy sources such as sun and wind. Although biogas can contribute to a certain degree of stability, it cannot fully compensate for fluctuations. Colocation data centers are faced with the challenge that energy requirements are primarily determined by their tenants. Customer awareness must be raised and support offered for adjustments. Hyperscale data centers, on the other hand, have the opportunity to exert a direct influence, for example by carrying out workloads during periods of high availability of green energy or by switching between locations with different levels of green energy availability.

Although the theoretical effects of demand management are significant, there are practical limits to the synchronisation of data processing with the supply of green energy, which is why the effects are currently estimated to be medium. Progress is anticipated in particular in the use of energy storage technologies by data centers in order to minimise external electricity requirements in times of low availability of green electricity, as well as in cooperation with energy suppliers in order to use these storage capacities to stabilise grid load peaks. Currently, around one in six data centers state that they have invested in battery storage technologies, with a larger number of operators planning investments in this direction.

NON-FOSSIL EMERGENCY POWER SUPPLY

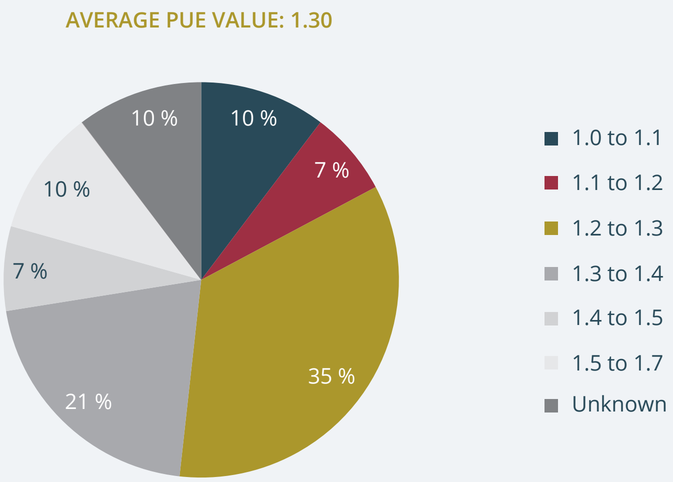
Although generators in data centers primarily function as backup solutions, they must run regularly for a short period of time for testing purposes. Recently, alternative technologies have increasingly been developed to reduce dependence on conventional diesel generators. Notable alternatives include, firstly, extended battery storage, which exceeds the capacity of conventional uninterruptible power supplies (UPS), which typically provide a backup time of six to ten minutes. The second alternative is hydrogen generators that utilise green energy sources. Although this technology is currently still associated with higher costs, the market is expected to adapt in the coming years.

At the same time, data centers are increasingly exploring the use of biodiesel as an environmentally friendly fuel alternative to generate both environmental benefits and maximise the value of their investments. The commitment to environmentally friendly alternatives can be seen in the implementation of the first hydrogen-powered backup fuel cell for data centers by NorthC Datacenters in the Netherlands – a company that is also active in Germany. This step has aroused great interest among data center operators in Germany to implement comparable technologies and thus promote the transition to more sustainable energy supply solutions.

ENERGY EFFICIENCY

Power Usage Efficiency (PUE) is a key figure in the discussion about the energy consumption of data centers. This indicates the ratio of the total energy consumption of a data center to the energy consumption of the IT equipment. A hypothetical data center with an energy consumption of 1 MWh for IT equipment and an additional 0.5 MWh for other purposes therefore has a PUE value of 1.5. Earlier generations of data centers were characterised by low efficiency, with PUE values of 2.0 or higher, mainly due to inefficient cooling systems and energy losses caused by inadequate uninterruptible power supplies (UPS) and lighting. According to the Energy Efficiency Act, data centers in Germany that go into operation from July 2026 must achieve a maximum PUE value of 1.2. Existing data centers that commence operations before 1 July 2026 must also comply with a PUE value of 1.5 from July 2027; from July 2030, a PUE of 1.3 will be required.

FIGURE 35: Question: What is the average realized PUE value of your data center(s) in Germany (NOT the „design PUE value")?

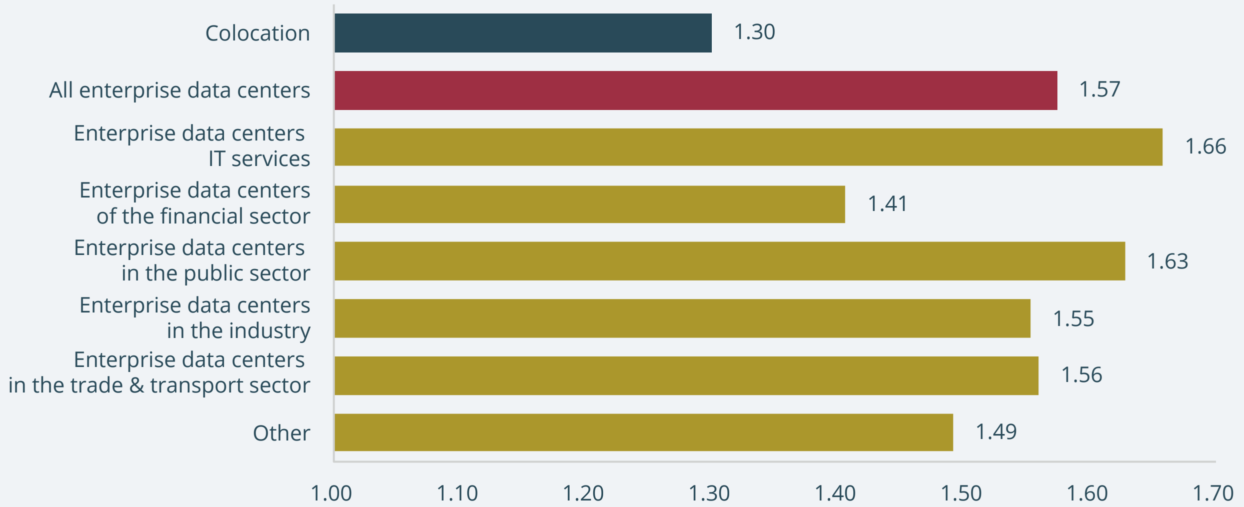


Source: Survey of colocation data center operators, 2024 (N=29)

The survey of colocation data center operators revealed that only one sixth of the facilities currently achieve a PUE value of less than 1.2. Nevertheless, a significant improvement in energy efficiency can be observed: On average, the colocation data centers of the 29 operators surveyed, achieve a PUE value of 1.3, although it should be noted that the average value determined is not weighted. The 29 colocation companies surveyed include both organisations that operate a large number of different data centers, which in turn provided an average value for their facilities, as well as operators of individual data centers that only provided their real PUE value.

In contrast, the market for enterprise data centers is less efficient, with an average PUE value of 1.57. The most efficient facilities are found in the financial sector with an average value of 1.41, while the IT services sector and the public sector, which include early adopters, have the lowest efficiency rates. By 2030, all existing data centers are expected to reduce their PUE value to a maximum of 1.3. This requirement implies significant investments in the demolition and new construction, modernisation, and upgrade of existing facilities or, alternatively, the closure and relocation to colocation data centers, which is critical from a sustainability perspective.

FIGURE 36: What is the average realized PUE value of your data center(s) in Germany (NOT the „design PUE value“) – by sector



Source: Survey of colocation data center operators, 2024 (N=29); survey of companies that operate their own (enterprise) data center, 2024 (N=203)

HEAT RECOVERY

Data centers play a central role in the current debate on sustainability in information and communication technology (ICT) due to their relatively high energy consumption. One aspect that is receiving increasing attention in this context is the possibility of heat recovery from the waste heat generated by computer and server utilisation. To date, a large number of projects for heat recovery from data centers have been locally limited and often involve the heating of office space within the same property. However, there is a tendency to expand this practice by increasing the connection of neighbouring office buildings, public facilities such as swimming pools and other local infrastructures.

The Energy Efficiency Act sets clear requirements for new data centers with a capacity of 1 megawatt (MW) or more: at least 10% of the heat generated must be reused by 2026 and 20% by 2028, or there must be a contract for the prompt supply of heat to operators of heating networks. Current surveys show that 28% of colocation data centers are able to feed their residual heat into existing heating networks, whereby 31 % are currently investing in corresponding technologies. In the enterprise data center segment, the proportion of facilities that use heat recovery is significantly lower.

The integration of heat recovery systems in data centers implies significant challenges for urban planning and site selection. An effective and cost-efficient connection to urban heating networks requires careful integration of data centers into urban or rural structures that have a need for district heating. The geographic distance to potential waste heat consumers represents a significant limitation.

Although data centers have a higher consumption of electrical energy due to their increased energy requirements and the increase in power density, this also results in an increased availability of waste heat that can be used for district heating networks. The progressive implementation of liquid cooling systems also promises an improvement in the quality of the heat emitted and opens up new perspectives for the utilisation of this resource in the heat supply.

WATER

In the context of data center sustainability efforts, the aspect of water consumption is becoming increasingly important alongside energy efficiency and heat recovery. Although the data center sector as a whole accounts for a small proportion of water consumption compared to other industries, individual large data centers or hyperscale campuses can have a significant local impact. One challenge in this area is that measures to reduce water consumption often represent a compromise for increasing energy efficiency, as the water is primarily used to cool the data centers and thus increase energy efficiency. A reduction in water usage efficiency (WUE) can therefore lead to a deterioration in power usage efficiency (PUE), which requires balanced management of both efficiency indicators.

The optimisation of water consumption in data centers does not focus exclusively on the direct reduction of consumption, but also includes the development of alternative water sources that do not compete with drinking water consumption. These include strategies such as the collection and storage of rainwater, the utilisation of surface water in regions where it is abundant, or the use of treated wastewater. Current data shows that around 20% of the colocation and hyperscale operators surveyed (Figure 33) have already invested in such alternative water sources, with a trend towards further investment in the next two years. In contrast, this topic appears to play a less central role in the planning and implementation of sustainability measures in enterprise data centers (Figure 34).

The consideration of water consumption in data centers therefore requires an integrated approach that takes into account both the efficiency of energy and water use in order to ensure both ecological and economic sustainability. The development and implementation of technologies and management strategies that enable a balanced relationship between these two efficiency indicators is of crucial importance for the future sustainability of the sector.

MEASURES IN PREPARATION FOR ENEFG

The analysis of the reactions of colocation and hyperscale data centers to the Energy Efficiency Act (Energieeffizienz-Gesetz, EnEfG) shows a broad spectrum of preparatory measures. Some operators report full compliance with the requirements, especially those who have recently put their facilities into operation and were therefore able to take the requirements of the law into account from the outset. Nevertheless, the majority of operators still need to take action. The preparations can be divided into several core areas:

- Data collection and reporting: Since the law was announced, data centers have begun to identify the data required for the energy efficiency register and in some cases have already started to collect it. The majority of operators are still in this phase, while some are already implementing an energy management system as required by law.
- Energy efficiency: Measures to increase energy efficiency, which are at the centre of the EnEfG, are being widely discussed. Some operators have already made extensive adjustments, including optimisations in the IT area and adjustments to the system temperatures. Future requirements are described by some as a wait-and-see position, while others mention the introduction of innovative cooling technologies such as liquid cooling.
- Renewable energy: The use of renewable energy is widespread among the data centers surveyed. Since the introduction of the EnEfG, operators who previously used conventional electricity have increasingly switched to renewable energy.
- Heat recovery and cogeneration: Heat recovery and cogeneration measures are also mentioned as ongoing activities, whereby these are predominantly implemented in data centers that already had corresponding plans. The integration of these technologies appears to be planned above all for new data center buildings, whereby heat recovery was already included in the plans.

In comparison, a different picture emerges for enterprise computing centres: around half of the companies surveyed have not yet made any preparations and do not appear to be aware of the relevance of the topic. For the other half, the measures vary. Enterprise data centers that own their own hardware often make efforts to reduce energy consumption by replacing servers and using the energy-saving options of IT equipment. Other widespread measures include switching to green electricity, installation of photovoltaic systems and the inspection and optimisation of cooling and UPS systems as well as lighting. There is a conspicuous lack of focus on monitoring and energy management systems and on activities in the area of heat recovery and cogeneration in the corporate sector.

MARKET STATISTICS (TABLES)

TABLE 5: Total number of German data centers

COUNTRYWIDE

	COLOCATION AND HYPERSCALE DATA CENTERS		ENTERPRISE DATA CENTERS		TOTAL	
IT Power (MW)	Facilities (#)	%	Facilities (#)	%	Facilities (#)	%
0.050–0.3	85	27.5	1,179	70.0	1,264	63.4
0.3–1	57	18.4	372	22.1	429	21.5
1–5	101	32.7	203	6.1	204	10.2
5–20	48	15.5	30	1.8	78	3.9
20 or more	18	5.8	0	0.0	18	0.9
Overall, # Facilities	309	100	1,684	100	1,993	100
Total number of providers	153					

METROPOLITAN REGION OF FRANKFURT AM MAIN

	COLOCATION AND HYPERSCALE DATA CENTERS	
IT Power (MW)	Company (#)	Facilities (#)
>0,3 MW	22	64

Source: Database for colocation & hyperscale data centers, 2024

TABLE 6: Total German data center IT Power

COUNTRYWIDE

	COLOCATION AND HYPERSCALE DATA CENTERS		ENTERPRISE DATA CENTERS		TOTAL	
IT Power (MW)	Agg. Total (MW)	%	Agg. Total (MW)	%	Agg.Total (MW)	%
0.050–0.3	17	1.3	83	13.9	100	5.1
0.3–1	33	2.4	149	25.1	182	9.4
1–5	196	14.5	155	26.1	351	18.1
5–20	478	35.4	208	35.0	686	35.3
20 or more	625	46.3	0	0.0	625	32.2
In total	1,349	100.0	595	100	1,944	100

METROPOLITAN REGION OF FRANKFURT AM MAIN

	COLOCATION AND HYPERSCALE DATA CENTERS	
IT Power (MW)	Agg. Total (MW)	%
>0.050	831	61.6

Source: Database for colocation & hyperscale data centers, 2024

METHODOLOGY OF RESEARCH

In this study, a multi-methodological approach was pursued, which is based on a combination of sector research and the implementation of two anonymous surveys. The aim was to gain a comprehensive understanding of the current market situation, forecast future developments and quantify the economic impact with the greatest possible precision. Various sources were consulted and methodically analysed to estimate the market size and prepare forecasts. The secondary research included the evaluation of existing studies, industry reports and publicly accessable databases to gather a wide range of relevant information. The supplementary surveys were designed to close specific data gaps and to obtain current assessments from market participants, while ensuring anonymity to promote unbiased and authentic responses. The integration of these different research methods and analyses enabled a holistic view onto the object of investigation and contributed to drawing well-founded conclusions about market dynamics and their economic implications.

FIGURE 37: Research approach

DATA CENTER DATABASE

- Market sizing
- Construction plans and investments
- Forecasting
- Geographical segmentation
- Economic impact

↑

OTHER SOURCES

Including publicly available statistics, benchmark data

DATA CENTER SURVEY

- Growth by region
- Service categories
- Sustainability (electricity, water, residual heat)
- Key challenges (shortage of skilled labour, availability of electricity and space, etc.)
- Technological trends
- Investments
- Effects of the regulations

COMBINED DATA

- Utilisation share of renewable energies
- Growth by region
- Socio-economic effects

SURVEYS

The data collection for this study comprised two separate surveys. The first survey was conducted between December 2023 and January 2024 and targeted decision-makers in colocation data centers. A total of 29 questionnaires were completed by managers, with the majority, but not all participants, being members of the German Datacenter Association. Despite the relatively small sample size, the participating companies together represent 71% of the total IT capacity (measured in megawatts, MW) of the colocation and hyperscale market in Germany, which emphasises the relevance and significance of the data collected.

The second survey took place in January 2024 and was aimed at decision-makers in enterprise data centres belonging to organisations with at least 150 employees in Germany. This survey resulted in 203 fully completed questionnaires. The broader participation base in the second survey allows for a more comprehensive analysis of the practices and perspectives of data centers within companies of different sizes and from different industries.

Both surveys were designed to gain in-depth insights into the current trends, challenges and strategies in the operation of data centers in Germany. By combining the results from both surveys with supplementary secondary data, it was possible to create a comprehensive basis for analysing the market dynamics and future development prospects of the data center sector.

COLOCATION AND HYPERSCALE DATABASE

The creation of a comprehensive database for co-location and hyperscale data centers is an essential basis for the precise quantification of the market. This database was developed by Pb7 Research using a combination of existing sources, online research and data validation processes and is continuously updated. Where information was missing, estimates were made using alternative indicators such as the number of racks or the floor space of the buildings. The aim was to provide a complete record of all existing (and, if publicly known, planned) data centers that offer colocation services with an IT capacity of at least 50 kW. The name of the operator, the location, the size of the data area, the building area and the IT capacity were recorded in the database. A total of 264 existing facilities were identified, plus 34 that are in the planning phase or under construction.

In order to fully reflect the market, an estimate was added for a group of smaller facilities, which corresponds to a market coverage of 0.7 %.

SIZING OF THE ENTERPRISE DATA CENTER MARKET

To quantify the enterprise data center market, a specific model was developed that combines demographic company data (including size, industry, geographic location) with information on the installed server base and the dimensions of the data centers per segment. By aggregating the survey results and calculating the average values per rack and megawatt, it was possible to quantify the number and total capacity of data center facilities (>50kW) owned by organisations. This methodical approach made it possible to generate well-founded estimates of the total size of various market aspects and thus provide an in-depth insight into the structure and dynamics of the data center sector in Germany.

ECONOMIC EFFECTS

A comprehensive approach was taken to determine the economic impact of data centers on the German economy, which includes direct, indirect and induced effects. The direct effects relate to the contribution to gross domestic product (GDP) and the employment effects directly generated by the activities of data centers. The turnover and employment data required for this were obtained by extrapolating the data specified by operator and combining it with the results from current surveys. This methodology was applied to hyperscale and colocation data centers and, to a limited extent, data on enterprise data centers was also used, drawing on findings from specific studies.

The calculation of the indirect effects, representing the GDP contribution of the supply chain, and the induced effects, resulting from the consumer spending of directly and indirectly employed workers, was done by applying national input/output statistics. The economic impact model created includes adjustments to these statistics based on the findings from specific studies on the spending patterns of data centers to optimise the accuracy of the model.

CREATE FORECASTS

A combined top-down and bottom-up analysis approach was used for the market forecasts. At the bottom-up level, planned expansions and construction projects were recorded and their likely realisation was forecast on the basis of realistic time frames. Potential projects that are not yet visible but are expected to be realised in the medium term were also taken into account. The top-down approach was used to compare this data with existing international market forecasts in order to identify any discrepancies and make corrections.

Investment figures, which are often mentioned in project announcements, were extrapolated to unspecified projects and the investment plans were distributed over the expected construction periods in order to estimate the annual investment volumes.

To quantify and forecast the colocation market, a model was developed that segments the market into traditional colocation data centers and hyperscale data centers. Sales per megawatt from specific research projects were used and compared with the sales figures of listed data center operators worldwide in order to estimate the differences in sales per megawatt for Germany in particular compared to other regions such as Europe or EMEA. A moderate price increase over the forecast period was assumed for future market development.

LIST OF ILLUSTRATIONS

LIST OF TABLES

ABOUT PB7 RESEARCH

Pb7 Research is an independent IT research company with many years of experience in the field of data centers. Pb7 Research provides independent research and consultancy aimed at the successful introduction of new technologies to European markets. Pb7 supports technology marketers and strategists by identifying and analysing markets, competitive opportunities and challenges, technology buyers in their decision making and helps policy makers with key statistics and market insights. Pb7 Research is a specialist in data center infrastructure and services, cloud, edge and IoT and other emerging technologies.

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ABOUT THE GERMAN DATACENTER ASSOCIATION E.V.

The German Datacenter Association e.V. (GDA) is the association of the data center industry in Germany and represents its interests vis-à-vis society, business and politics. The member companies of the GDA represent the diversity and innovative strength of the data center ecosystem. The association offers them a platform to jointly strengthen the growth of the industry and improve their perception in society, business and politics. In addition, the GDA represents its members in the relevant committees with regard to laws, regulations, standards, norms and political issues. The declared aim is to sustainably improve the framework conditions for the operation of data centers in Germany and to increase the investment attractiveness of German locations. The German Datacenter Association e.V. was founded in 2018 and is based in Frankfurt am Main.

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