Data centers 2021

Data center boom in Germany continues

Cloud computing drives the growth of the data center industry and its energy consumption

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The energy consumption of data centers continues to increase. At 17 billion kWh, data centers consumed 6.5 % more electricity in 2021 than in 2020. The main reason for the growth in energy consumption is the expansion of cloud data centers in Germany and the associated increase in the number of large data centers. However, traditional data centers operated by companies themselves also continue to have a high share of data center capacities in Germany.

These are the results of a recent study by the Borderstep Institute on the development of the energy consumption of data centers in Germany.

The growth in the energy consumption of data centers is mainly due to the increased demand for IT performance from data centers. Although servers are becoming more and more powerful and the utilization of IT systems is increasing, especially in cloud data centers, the sharp increase in power demand is leading to higher electricity consumption in data centers in Germany (figure 1). Of the 17 billion kWh of electricity consumed in data centers in 2021, almost 11 billion kWh went to IT components (servers, storage and network). Since 2010, the electricity demand of the IT components in the data centers has thus almost doubled. In comparison, the energy consumption of the data center infrastructure (cooling/uninterruptible power supply (UPS), etc.) increased only moderately from 4.6 to 6.1 billion kWh between 2010 and 2021. Therefore, the efficiency of the data center infrastructure has improved significantly. The so-called PUE value[1] is used as a measure of the efficiency of the data center infrastructure. The average PUE value of data centers and small IT installations in Germany improved from 1.82 to 1.56 between 2010 and 2021.

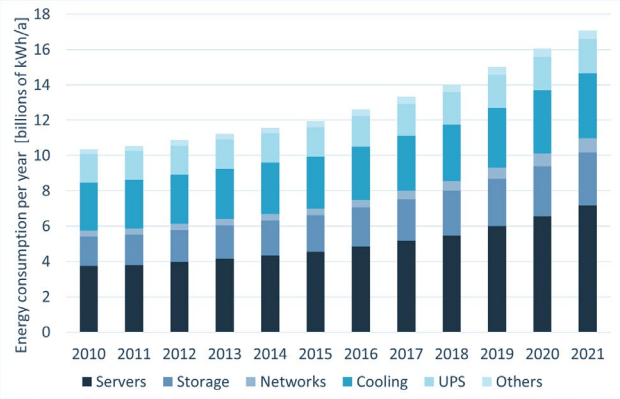

Figure 1: *Energy consumption of servers and data centers in Germany from 2010 to 2021 (Source: Borderstep)*

If current trends continue, the energy consumption of data centers in Germany will continue to rise in the future despite the significant efficiency gains in IT and infrastructure components. By 2030, an increase to about 28 billion kWh is expected. (Hintemann, Graß, Hinterholzer & Grothey, 2022).

Servers need more and more power

A major reason for the rising energy consumption is the increasing power consumption of the servers. If we look at the 2-CPU servers measured for the SPECPower® benchmark, they have a maximum power consumption today that is almost two and a half times as high as in 2007 (figure 2). Despite this increase in power consumption, today's systems are many times more efficient when compared to the increase in computing power. The maximum computing power of the systems has increased by a factor of 50 in some cases over the same period.

[1] The Power Usage Effectiveness (PUE) value indicates the ratio of the annual energy demand of the entire computing centre to the annual energy demand of the IT of the computing centre.

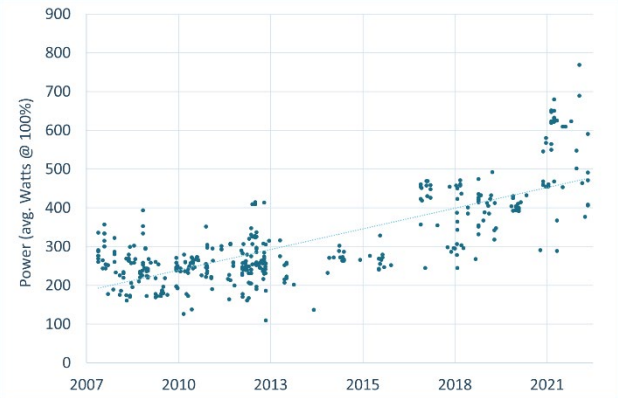

Figure 2: *Maximum power consumption of servers with two CPUs in the SPECpower® benchmark (2007 - 2021)*

Strong growth of cloud data centers

According to current research by Eurostat, the share of companies (10 employees or more) in Germany using cloud services will be 42% in 2021, at the average European level. Especially in the Scandinavian countries Sweden (75 %), Finland (75 %), Denmark (65 %) and Norway (64 %), cloud computing is used significantly more. But also, in the Netherlands (65%) and Italy (60%) there is a significantly higher share of companies using cloud services. However, cloud use in Germany has been increasing significantly in recent years. Between 2018 and 2021 alone, the number of cloud-using companies almost doubled (Eurostat, 2022). One reason for this is not least the Corona pandemic. Cloud providers in particular benefited from the digitalization boost associated with the pandemic in the past year and will probably also emerge stronger from the crisis in the long term. (eco & Arthur D. Little, 2020). The significant growth in demand for cloud services is one reason for the boom in the construction of large data centers in Germany, which has been going on for years. The cloud currently accounts for one-third of data center capacity in Germany. By 2025, cloud computing is expected to become the dominant deployment model in Germany. Especially in the Frankfurt Rhine-Main and Berlin/Brandenburg regions, there are currently a number of new data center projects with rated IT power in the order of 100 MW and more. (Hintemann et al., 2022).

Own operation of data centers continues to be very important

Despite the strongly increasing share of cloud computing in data center capacities in Germany, the in-house operation of data centers is also an important issue for a large proportion of companies. The capacities of traditional data centers in Germany have so far remained at a constant level. The growth in total capacities is almost exclusively due to cloud data centers. It is also to be expected that this development will change little in the future. According to a recent representative survey, only about 5 % of companies are planning to do without their own data centers. (Hintemann et al., 2022).

Waste heat from data centers must be recovered for climate protection

Against the backdrop of advancing climate change and the challenge of reducing dependence on fossil fuels such as oil and gas, the use of waste heat is becoming increasingly important. Data centers can make a significant contribution to this. Up to now, the electricity consumed in data centers has been released unused into the environment in the form of heat. Until now, this was due in particular to the lack of economic efficiency of waste heat utilization from data centers. (Clausen, Hintemann & Hinterholzer, 2020). In the future, however, it can be assumed that the conditions will be significantly different, so that the use of waste heat from data centers can become very important. The reasons for this are the changing framework conditions of energy supply, new technical approaches such as liquid cooling of servers or the use of artificial intelligence to optimize heat extraction and heat networks.

Worldwide development: High share of crypto-mining in the increasing energy demand of data centers

If one analyses the available studies and publications on the worldwide energy consumption of data centers, no uniform picture emerges. Some researchers assume a significant increase in energy consumption worldwide (Andrae, 2019; Belkhir & Elmeligi, 2018; Petit, Carlini & Avelar, 2021; The Shift Project, 2019). In other studies, on the other hand, the energy consumption of data centers has remained almost constant in recent years. (IEA, 2017; Masanet, Shehabi, Lei, Smith & Koomey, 2020; Shehabi, Smith, Masanet & Koomey, 2018). For the year 2020, for example, the calculations range from about 200 billion kWh to almost 900 billion kWh.

With the help of the structural bottom-up model of data centers developed for Germany, an estimate of the development of the global energy consumption of data centers can be made. This can be done on the basis of worldwide sales figures for servers and by adjusting the model assumptions. Taking into account uncertainties due to parameter variations, a global energy consumption of data centers in the order of 350 to 500 billion kWh/a can be calculated in 2021[2] . Mining[3] of cryptocurrencies is responsible for about a quarter of this energy consumption. If one analyses various model calculations on the subject

[2] An article on this topic for a scientific journal is currently being prepared.

[3] When mining cryptocurrencies, high computing power is usually used in a network to ensure that the currencies are tamper-proof. During this process, new "coins" are created ("mining") and distributed to the miners as a reward for their computing power.

of crypto-mining (CBECI, 2022; Digiconomist, 2022a, 2022b) an energy consumption in the order of 80 to 120 billion kWh/a seems likely.

Methodology of the study

This study is based on work by the Borderstep Institute on the development of data centers in Germany.

According to the underlying system, data centers are all closed spatial units such as server cabinets, server rooms, parts of buildings or entire buildings in which IT components such as servers, storage and network components are installed. Small IT installations that centrally provide computing and storage services are also explicitly considered data centers. The development of data center capacities is calculated in particular on the basis of the server equipment in the data centers. The different performance classes of servers are also taken into account.

The calculations are made with the help of a comprehensive structural bottom-up model of the data center landscape in Germany and Europe, which was developed at the Borderstep Institute and is updated annually (Fichter & Hintemann, 2014; Hintemann, 2017a, 2020; Hintemann, Clausen, Beucker & Hinterholzer, 2021; Hintemann, Fichter & Stobbe, 2010; Hintemann et al., 2022; Hintemann & Hinterholzer, 2019, 2020; Hintemann, Hinterholzer, Montevecchi & Stickler, 2020; Hintemann et al., 2020; Stobbe et al., 2015). The model describes the data centers in various size classes in terms of their equipment with different server types, storage systems and network infrastructures. The age structure of the servers and the energy requirements of the various server types in different operating states are also taken into account. In addition, the data center infrastructures such as air conditioning, power supply, UPS, etc. are modelled.

The following sources in particular were used for the current calculations:

- Study " Rechenzentren in Deutschland - Aktuelle Marktentwicklungen " (Hintemann et al., 2022)
- Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market" study (Hintemann et al., 2020)
- Study "Data Centers in Europe - Opportunities for Sustainable Digitalization - Part 1" (Hintemann & Hinterholzer, 2020)
- Study " Entwicklung des IKT-bedingten Strombedarfs in Deutschland " - Study by Fraunhofer IZM and Borderstep on behalf of the Federal Ministry for Economic Affairs and Energy (Stobbe et al., 2015)
- Current results of studies on the development of the data center market (CBRE, 2017, 2018, 2020; Cisco, 2015, 2016; Gartner, 2020; Hintemann, 2014, 2017b; Hintemann & Clausen, 2018a, 2018b; Hintemann, Fichter & Schlitt, 2014; Howard-Healy, 2018)
- Data from the market research institute Techconsult on the market development of server, storage and network components (eanalyzer) (Techconsult, 2014, 2015, 2016)
- Data from the market research institutes IDC and EITO on the market development for servers in Germany and Europe (EITO, 2014, 2019; IDC, 2018, 2021)
- Scientific literature and manufacturer information on the development of energy consumption of services, storage and network products and other efficiency technologies for data centers.

Sources:

Andrae, A. S. G. (2019). Projecting the chiaroscuro of the electricity use of communication and computing from 2018 to 2030.

Belkhir, L. & Elmeligi, A. (2018). Assessing ICT global emissions footprint: Trends to 2040 & recommendations. *Journal of Cleaner Production*, *177*, 448-463.

CBECI. (2022). Cambridge Bitcoin Electricity Consumption Index (CBECI). Accessed 16.6.2022. Available at: https://ccaf.io/cbeci/index

CBRE. (2017). *European Data Centres Market Review. Q4 2016.* London. Accessed 10.6.2021. Available at: https://www.cbre.de/de-de/research/European-Data-Centres-MarketView-Q4-2016

CBRE. (2018, March 21). European data centre capacity in demand again exceeds 100 MW. *European data centre capacity in demand exceeds 100 MW again*. Accessed 4.4.2018. Available at: http://news.cbre.de/nachgefragte-leistung-europaischer-rechenzentren-ubersteigt-erneut-100-mw-wert

CBRE. (2020). *Europe Data Centres Q4 2019*. Accessed 19.3.2020. Available at: https://www.cbre.de/en/global/research-and-reports/featured-reports-global/featured-reports-emea

Cisco. (2015). *Cisco Global Cloud Index: Forecast and Methodology 2014-2019.* Available at: http://www.cisco.com/c/en/us/solutions/collateral/service-provider/global-cloud-index-gci/Cloud_Index_White_Paper.pdf

Cisco. (2016). *Cisco Global Cloud Index: Forecast and Methodology 2015-2020.* Accessed 10.10.2017. Available at: https://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/global-cloud-index-gci/white-paper-c11-738085.pdf

Clausen, J., Hintemann, R. & Hinterholzer, S. (2020). *Wirtschaftlichkeit der Abwärmenutzung aus Rechenzentren in Deutschland.* Background paper. Berlin: Borderstep Institut.

Digiconomist. (2022a). Bitcoin Energy Consumption Index. Accessed 16.6.2022. Available at: https://digiconomist.net/bitcoin-energy-consumption

Digiconomist. (2022b). Ethereum Energy Consumption Index. Accessed 23.5.2022. Available at: https://digiconomist.net/ethereum-energy-consumption

eco & Arthur D. Little. (2020). *The Internet Economy in Germany 2020-2025: Impact of the Corona Crisis*. Accessed 10.5.2020. Available at: https://www.eco.de/studie-internetwirtschaft-20-25-corona-preprint/

EITO. (2014). *EITO Costumized Report for Borderstep.* Berlin: EITO.

EITO. (2019). *EITO Customized Report for Borderstep.* Berlin: EITO.

Eurostat. (2022). Cloud computing services. Accessed 29.7.2022. Available at: https://ec.europa.eu/eurostat/data-browser/view/isoc_cicce_use/default/bar?lang=en

Fichter, K. & Hintemann, R. (2014). Beyond Energy: Material Stocks in Data Centers, Taking Resource Efficiency into Account in Green IT Strategies for Data Centers. *Journal of Industrial Ecology*, (forthcoming). https://doi.org/DOI: 10.1111/jiec.12155

Gartner. (2020, March 19). Gartner Says Worldwide Server Revenue Grew 5.1% in the Fourth Quarter of 2019, While Shipments Increased 11.7%. *Gartner*. Accessed 19 Mar. 2020. Available at: https://www.gartner.com/en/newsroom/press-releases/2020-03-19-gartner-says-worldwide-server-revenue-grew-5-percent-in-the-fourth-quarter-of-2019-while-shipments-increased-11-percent

Hintemann, R. (2014). Consolidation, Colocation, Virtualization, and Cloud Computing - The Impact of the Changing Structure of Data Centers on Total Electricity Demand. In L. Hilty & B. Aebischer (Eds.), *ICT Innovations for Sustainability. Advances in Intelligent Systems and Computing*. Berlin, Heidelberg: Springer.

Hintemann, R. (2017a). *Rechenzentren 2016. Trotz verbesserter Energieeffizienz steigt der Energiebedarf der deutschen Rechenzentren im Jahr 2016.* Berlin: Borderstep Institute for Innovation and Sustainability. Available at: https://www.borderstep.de/wp-content/uploads/2017/03/Borderstep_Rechenzentren_2016_Stand_07_03_2017_finaln-1.pdf

Hintemann, R. (2017b). *Energieeffizienz und Rechenzentren in Deutschland – weltweit führend oder längst abgehängt? - Presentation*. Berlin: Netzwerk energieeffiziente Rechenzentren - NeRZ. Accessed 25.10.2017. Available at: https://www.borderstep.de/wp-content/uploads/2017/07/NeRZ-Studie-Rechenzentrumsmarkt-30-06-2017.pdf

Hintemann, R. (2020). *Data centres 2018. Efficiency gains are not enough: Energy demand of data centres continues to rise significantly.* Berlin: Borderstep Institute. Available at: https://www.borderstep.de/wp-content/uploads/2020/03/Borderstep-Rechenzentren-2018-20200324rev.pdf

Hintemann, R. & Clausen, J. (2018a). *Bedeutung digitaler Infrastrukturen in Deutschland. Sozioökonomische Chancen und Herausforderungen für Rechenzentren im internationalen Wettbewerb. Berlin. Available at*. Berlin. Accessed 14.6.2018. Available at: https://www.eco.de/wp-content/uploads/dlm_uploads/2018/06/DI_Studie.pdf

Hintemann, R. & Clausen, J. (2018b). *Potenzial von Energieeffizienztechnologien bei Colocation Rechenzentren in Hessen*. Berlin: Borderstep Institute for Innovation and Sustainability. Accessed 26.4.2018. Available at: https://www.digitalstrategie-hessen.de/rechenzentren

Hintemann, R., Clausen, J., Beucker, S. & Hinterholzer, S. (2021). *Studie zu Nachhaltigkeitspotenzialen in und durch Digitalisierung in Hessen* . Study for Hessen Trade & Invest GmbH on behalf of the Hessian State Chancellery, Hessian Minister for Digital Strategy and Development. Wiesbaden: Hessian State Chancellery, Minister for Digital Strategy and Development.

Hintemann, R., Fichter, K. & Schlitt, D. (2014). Adaptive computing and server virtualization in German data centres - Potentials for increasing energy efficiency today and in 2020. In Marx Gómez, Sonnenschein, Vogel, Winter, Rapp, & Giesen (Eds.), *Proceedings of the 28th Conference on Environmental Informatics - Informatics for Environmental Protection, Sustainable Development and Risk Management* (pp. 477-484). Oldenburg: BIS. Accessed 25.1.2015. Available at: http://enviroinfo.eu/sites/default/files/pdfs/vol8514/0477.pdf

Hintemann, R., Fichter, K. & Stobbe, L. (2010). Materialbestand der Rechenzentren in Deutschland-Eine Bestandsaufnahme zur Ermittlung von Ressourcen- und Energieeinsatz. *Study within the framework of the UFO Plan project "Product-related approaches in information and communication technology" (funding code 370 893 302), commissioned by the Federal Environment Agency*.

Hintemann, R., Graß, M., Hinterholzer, S. & Grothey, T. (2022). *Rechenzentren in Deutschland - Aktuelle Marktentwicklungen*. Bitkom. Accessed on 15.4.2022. Available at: https://www.bitkom.org/Bitkom/Publikationen/Rechenzentren-in-Deutschland-2022

Hintemann, R. & Hinterholzer, S. (2019). Energy Consumption of Data Centers Worldwide - How will the Internet become Green? Lappeenranta, Finland. Accessed 8 Aug. 2019. Available at: http://ceur-ws.org/Vol-2382/ICT4S2019_paper_16.pdf

Hintemann, R. & Hinterholzer, S. (2020). *Data Centres in Europe - Opportunities for Sustainable Digitalisation - Part 1*. Berlin: Alliance to Strengthen Digital Infrastructures in Germany. Accessed on 11.6.2020. Available at: https://digitale-infrastrukturen.net/studie-nachhaltige-digitalisierung-in-europa/

Hintemann, R., Hinterholzer, S., Montevecchi, F. & Stickler, T. (2020). *Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market*. Berlin, Vienna: Borderstep Institute & Environment Agency Austria. Available at: https://op.europa.eu/en/publication-detail/-/publication/bf276684-32bd-11eb-b27b-01aa75ed71a1/language-en/format-PDF/source-183168542

Howard-Healy, M. (2018). *Co-location Market Quarterly (CMQ) brief - presentation at BroadGroup's Knowledge Brunch in Frankfurt*. Broadgroup.

IDC. (2018). *Server Market and Enterprise Storage Systems By Country 2014-2017*.

IDC. (2021). *IDC Quarterly Enterprise and Cloud Infrastructure Trackers - Custom Market Intelligence - Prepared for Borderstep*.

IEA. (2017). *Digitalization & Energy*. Accessed 20 Jan. 2019. Available at: https://www.iea.org/reports/digitalisation-and-energy

Masanet, E., Shehabi, A., Lei, N., Smith, S. & Koomey, J. (2020, February 28). Recalibrating global data centre energy-use estimates. *Science*. Accessed 4.3.2020. Available at: https://science.sciencemag.org/content/367/6481/984

Petit, V., Carlini, S. & Avelar, V. (2021). *Digital economy and climate impact: A bottom-up forecast of the IT sector energy consumption and carbon footprint to 2030.* Nanterre: Schneider Electric. Available at: https://www.se.com/ww/en/insights/tl/electricity-4-0/digital-economy-and-climate-impact

Shehabi, A., Smith, S. J., Masanet, E. & Koomey, J. G. (2018). Data centre growth in the United States: decoupling the demand for services from electricity use. *Environmental Research Letters*, *13*(12).

Stobbe, L., Hintemann, R., Proske, M., Clausen, J., Zedel, H. & Beucker, S. (2015). *Entwicklung des IKT-bedingten Strombedarfs in Deutschland - Study commissioned by the Federal Ministry for Economic Affairs and Energy*. Berlin: Fraunhofer IZM and Borderstep Institute. Available at: http://www.bmwi.de/BMWi/Redaktion/PDF/E/entwicklung-des-ikt-bedingten-strombedarfs-in-deutschland-abschlussbericht,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf

Techconsult. (2014). Data from the eanalyzer. Available at: www.eanalyzer.biz

Techconsult. (2015). Data from the eanalyzer. Available at: www.eanalyzer.biz

Techconsult. (2016). Data from the eanalyzer. Available at: www.eanalyzer.biz

The Shift Project. (2019). *LEAN ICT- Towards digital sobriety*. Accessed 18 Apr. 2019. Available at: https://theshiftproject.org/en/article/lean-ict-our-new-report/

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