Borderstep Institute for Innovation and Sustainability

Data centers 2018

Cloud computing boosts growth

Efficiency gains are not enough: Data center energy consumption continues to rise significantly

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In 2018, the power requirements of data centers in Germany rose significantly again. Compared to the previous year, the demand for electrical energy by servers and data centers increased by 6% to 14 billion kWh. This growth is primarily due to the strong expansion of cloud computing capacity in Germany. Substantial new data center capacities were built up, particularly in the greater Frankfurt area, but also at other locations. This development is expected to continue in the future. Trends such as edge computing and artificial intelligence are expected to lead to a significant expansion of data center infrastructures in Germany, Europe and worldwide. If the existing efficiency potentials are not realized, the energy consumption of data centers will continue to rise significantly.

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

Although there have been very significant improvements in the energy efficiency of data centers in recent years, the sharp rise in demand for centralized computing power has led to a further increase in the energy consumption of data centers in Germany (**Figure 1**). In particular, the IT components (servers, storage and network) will require 8.5 billion kWh of electrical energy in 2018, significantly more than in 2010 (5.8 billion kWh). The average PUE value[1] of data centers in Germany fell from 1.98 to 1.70[2] between 2010 and 2018. This increased the efficiency of the data center infrastructure by 16% on average.

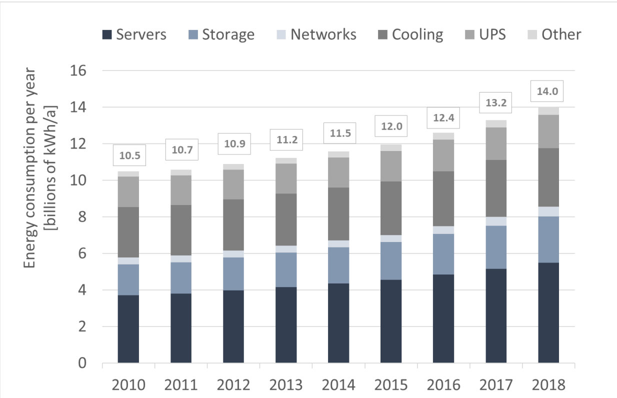

Figure 1: *Energy consumption of servers and data centers in Germany in the years 2010 to 2018 (Source: Borderstep)*

If past trends continue, the energy consumption of data centers in Germany will continue to rise, increasing by 50% from 2018 to 2030. However, this development is not inevitable. On the basis of analyses and evaluations of more than 60 new energy and resource-saving technologies conducted in the TEMPRO project (Hintemann & Hinterholzer, 2018), the project partners already implemented some particularly promising technologies as prototypes.

If the existing technical efficiency potentials are successfully exploited, the energy consumption of data centers in Germany could even be reduced by 25% by 2030 despite the strong expansion of data center infrastructures, as was determined in the TEMPRO project.

1 The Power Usage Effectiveness (PUE) value indicates the ratio of the annual energy consumption of the entire data center to the annual energy consumption of the data center's IT components.

2 The stand-alone servers, which are normally operated without their own air conditioning, are not included in the calculation of these values. Taking the stand-alone servers into account, the average PUE value in Germany improved from 1.82 in 2010 to 1.63 in 2018.

Cloud and edge computing, artificial intelligence: Energy consumption of data centers is expected to continue to rise

Increasing digitalization and the associated new applications, such as in the field of artificial intelligence (AI), but also the significant increase in cloud and edge computing capacities will lead to a growing demand for data center infrastructures.

Growth in the data center market is driven primarily by the rapidly increasing use of cloud services. International cloud computing providers in particular are currently expanding their data center capacity in Germany vigorously. Because of economies of scale, particularly efficient data center infrastructure and typically high server utilization, cloud computing data centers are often significantly more efficient than traditional data centers (Bizo, 2019; Shehabi et al., 2018). To date, cloud data centers in Germany have been established in addition to the existing traditional data centers. Hardly any traditional on-premise data centers have been dismantled. As a result, despite the higher efficiency of cloud computing solutions, the overall energy consumption of data centers continues to rise (**Figure 2**).

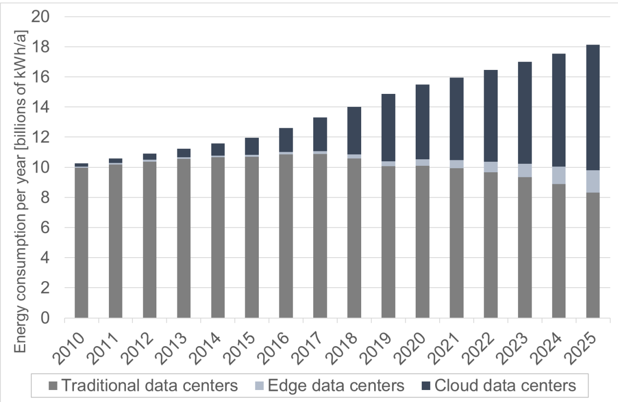

Figure 2: *Development of the electricity consumption of data centers in Germany with share of cloud and edge data centers from 2010 to 2018 and forecast until 2025 (Source: Borderstep)*

In regional terms, the greater Frankfurt area in particular is benefiting from growth in cloud computing. Investors often decide to construct new data centers in Frankfurt because of the good network connection through DE-CIX and the geographical proximity to the cloud capacities already available there. This is also confirmed by the analysts of the real estate service provider CBRE, who currently see the Frankfurt area as the strongest growing market in Europe. Most of the additional data center capacities in Europe are to be built in Frankfurt over the next two years (CBRE, 2020).

In the future, edge data centers will also have an increasing share of the energy consumption. In 2025, edge data centers in Germany will probably require 1.5 billion kWh of electrical energy. With the further expansion of 5G mobile phone networks and edge computing applications in areas such as Industry 4.0 applications, Autonomous Driving and Smart City, the energy consumption of edge data centers is expected to rise to around 4.5 billion kWh/a by 2030. In a scenario with increased expansion of edge computing, calculations in the TEMPRO project even indicate that edge computing could account for 30% of the energy consumption of all data centers.

New applications, especially in the field of artificial intelligence, may cause increasing energy consumption in data centers. AI is increasingly penetrating the human habitat (Reinsel et al., 2018; Schneider & Ziyal, 2019; Walsh, 2018). AI solutions can be found everywhere, from the living room with speech recognition solutions to cloud solutions for deep learning applications to use in critical infrastructures (e.g. in efficient and sustainable energy network management systems). This development has a variety of environmental impacts. On the one hand, AI offers many opportunities to make our living and working environments more sustainable. There are promising fields of application, especially for a better understanding of the Earth, the climate and the environment, as well as in the areas of agriculture, energy and mobility (Jetzke et al., 2019). As AI becomes more successful and opens up new areas of application, its resource requirements increase as well. Some deep learning applications, simulations and prognoses in particular demand enormous amounts of computing power and require large amounts of energy and resources. Researchers at MIT have calculated that the training of a single AI application for speech recognition generates five times as much CO_2 as a car during its entire lifetime (Hao, 2019; Strubell et al., 2019).

Precisely because of the great potential of AI and the possibility of accessing AI applications from any smartphone or other intelligent device, it is assumed that the use of AI technologies will continue to increase dramatically in the future (Hintemann & Hinterholzer, 2019). In the period from 2016 to 2021 alone, the workloads for the field of "Database/Analytics/IOT" in data centers worldwide are expected to increase by a factor of 2.5 (Cisco, 2018).

International development: Studies paint different pictures

An analysis of the internationally available studies and publications on the energy consumption of data centers does not produce a uniform picture. Some researchers assume an enormous increase in energy demand worldwide. This could increase from 200 billion kWh in 2010 to 2,000 to 3,000 billion kWh by 2030 (Andrae, 2019; Andrae & Edler, 2015; Belkhir & Elmeligi, 2018; The Shift Project, 2019). In contrast, other studies calculated that the energy consumption of data centers was practically constant in recent years (IEA, 2017; Masanet et al., 2020; Shehabi et al., 2018). For example, the calculations for 2020 range from 200 billion kWh to 900 billion kWh.

The wide range of the calculation results shows that there is still a great need for research and information in the field of the energy consumption of data centers. From Borderstep's point of view, neither the pessimistic calculations yielding very high energy consumption nor the optimistic calculations resulting in practically constant energy consumption in recent years are plausible. The pessimistic calculations cannot be supported by the established figures for hardware sales and equipment in data centers. The following facts in particular contradict that the energy consumption of the data centers has remained practically constant:

- A large number of independent studies (CBECI, 2019; Digiconomist, 2019; Kamiya, 2019; Rauchs et al., 2018) calculated that Bitcoin mining alone required about 60 to 70 billion kWh of electrical energy in 2019. If other cryptocurrencies are also included, it can be assumed that 70 to 90 billion kWh/a of electrical energy is currently required for cryptocurrency mining.

- Many large and medium-sized new data centers are being built worldwide, especially by hyperscale cloud providers. According to analysts, new data center construction has been setting records for years. At the four data center locations London, Frankfurt, Paris and Amsterdam alone, data center capacities have quadrupled. (CBRE, 2020; CBRE Global Corporate Services, 2017).

- So far, hardly any capacities at on-premise data centers have been reduced in Europe. At present, a trend can be seen that data is being migrated from the cloud back into the company's own data center even as hybrid cloud solutions are seeing increased use (Alffen, 2019; Vanson-Bourne, 2019).

- Since 2010, the number of servers worldwide has increased by about 50%. The number of server sales worldwide has increased very significantly, especially in 2018 and 2019 (Gartner, 2019, 2020; IDC, 2020).

- Data center capacities are experiencing particularly strong growth in the Asian market. A current report indicates that data center energy consumption in China alone reached 161 billion kWh in 2018 (Greenpeace & North China Electric Power University, 2019).

- The European data center market is also growing very significantly. Various scientific studies assume that the energy consumption of data centers in Europe has risen markedly (Bio by Deloitte & Fraunhofer IZM, 2016; Hintemann, 2019; Prakash et al., 2014). The studies indicate that by 2020, the energy consumption of data centers in Europe will be about 30% higher than in 2010.

According to estimates by the Borderstep Institute, the energy consumption of data centers worldwide in 2018 was about 400 billion kWh.

Methodology of the study

The present study was conducted as part of the TEMPRO project—"Total Energy Management for Professional Data Centers".

According to the underlying classification, data centers are defined as all self-contained spatial units such as server cabinets, server rooms, parts of buildings or entire buildings in which at least three physical servers are installed. The development of data center capacities is calculated on the basis of the server equipment in the data centers and other factors. The different performance classes of servers are also taken into account here.

The calculations are based on a comprehensive structural model of the data center landscape in Germany, which was developed at the Borderstep Institute and is updated annually (Fichter & Hintemann, 2014; Hintemann et al., 2010; Hintemann, 2017b; Hintemann & Hinterholzer, 2019; Stobbe et al., 2015). In the model, the data centers in Germany are described in different size classes in terms of their 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. Furthermore, the data center infrastructures such as air conditioning, power supply, UPS, etc. are modeled for different size and redundancy classes.

The following sources, among others, were used for the calculations:

- Study "Development of ICT-related electricity demand in Germany"–Study by Fraunhofer IZM and Borderstep on behalf of the Federal Ministry of Economics and Energy (Stobbe et al., 2015).
- Current results of studies on the development of the data center market (CBRE, 2018, 2020; CBRE Global Corporate Services, 2017; Cisco, 2015, 2016; Gartner, 2020; Hintemann, 2014, 2017a; Hintemann et al., 2014; Hintemann & Clausen, 2018a, 2018b; Howard-Healy, 2018)
- Data from the market research institute Techconsult on market development for servers, 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; IDC, 2018)
- Scientific literature and manufacturer information on the evolution of the energy consumption of servers, storage and networking products as well as emerging data center efficiency technologies.

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