# Energy efficiency of data centers - A system-oriented analysis of current development trends

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## Abstract

The advancing digitization of all areas of the economy and society is generating significantly increasing demand for processing power. More and more data centers of ever larger size are being built worldwide, and their electricity consumption is constantly on the rise. Forecasts project a significant increase in the global electricity consumption of data centers in the next five years. The presentation discusses the development of data centers' energy consumption and energy efficiency, using the example of Germany. A recent study by Borderstep and Fraunhofer IZM for the Federal Ministry for Economic Affairs and Energy shows that the electricity consumption of data centers in Germany grew by 15% to 12 billion kilowatt hours from 2010 to 2015. This was the case in spite of considerable efficiency gains in IT hardware and data center infrastructure. If the current trends in IT usage continue, German data centers' energy consumption will increase further and exceed 14 billion kWh in 2020. Reasons for this growth are in particular the increasing number of internet-enabled end-user devices and networked sensors. In addition, more and more processing is being shifted from end-user devices to data centers.

## 1 Introduction

How the interaction of the individual components of the ICT systems—servers, storage, network systems, and data center infrastructure—is managed is of key importance to the future energy consumption of data centers. What will the data center landscape of the future look like? Will there continue to be a large number of small, decentralized data centers operated by small and medium-sized user companies? Or will processing power increasingly shift to the mega-data centers operated by colocation and cloud providers, which can usually be run significantly more efficiently?

Against this background, this paper discusses the following questions:

- What are the significant market trends and technical trends affecting the energy efficiency of data centers?
- What are the main factors consuming electricity in data centers, and how will the shares of the various electricity consumers within data centers develop in the future?
- What are the impacts of the structure of data centers on their energy consumption? What will the effects of the trend toward mega-data centers and cloud data centers be?

## 2 Methodology

The methodology described in the following is applied to answer these three questions.

The key basis for calculating IT energy consumption is a study prepared for the German Federal Ministry of Economic Affairs [1]. In this study the energy consumption of all ICT in Germany was determined for the years 2010 and 2015 and forecast for 2020 and 2025. The detailed model used for the calculations is based on a structured quantitative survey of the stock of ICT devices in various areas of application. Four basic parameters were determined for each product group included in the model:

- Type and number of devices
- Load-dependent electric power consumption
- User-specific applications and load profiles
- Dependencies on other product groups

For each product the stock of devices is determined from sales figures of previous years. Thus, the model also represents the age distribution of the devices. For each year of manufacture, electric power consumption is determined for various load statuses (e.g., off, idle, full load). The usage profiles are also determined for each product group for the years analyzed.

The model is based on a database with several thousand datasets. The sources of the data for the study are sales figures from market research firms, publicly accessible market statistics, technical data sheets, and

consumer studies. Comprehensive assumptions resulting from an analysis of technical and usage-related trends were made for the forecasts for 2020 and 2025.
A Delphi survey of ten selected data center industry experts was conducted during the period November 2015 to January 2016 in order to look into the development of the structure of data centers in Germany. They include several CEOs and technical experts from major cloud and colocation data centers as well as from companies providing equipment, planning, contracting, and other services for data centers. The analysis also takes the findings of current studies on the data center market into account [2]–[9]. Borderstep Institute's comprehensive structural model of the data center landscape in Germany was employed for the calculations.

# 3 Market trends and technical trends

## 3.1 Market trends

The data center market in Germany is growing. IT hardware expenditures increased by 3.5% in 2015. Growth of storage systems was particularly strong (+6%). Turnover for new construction and modernization of data center infrastructure also showed significant increases of just under 10% [7].

The trend toward cloud computing is shifting more and more processing power from the end-user device or from small data centers to larger ones. This process is changing the data center landscape long-term. According to forecasts by Cisco, the fraction of the cloud workload in data centers will increase globally to 86% by 2019 [10]. Even if the trend toward cloud computing is not as strong in Germany as in some other parts of the world [11], use of cloud computing is increasing significantly here as well. 54% of German companies used cloud computing in 2015 [12].

Besides the trend toward cloud computing, colocation data centers are also showing significant growth. Analysts currently forecast significantly accelerated growth in this market segment with annual growth averaging approx. 7.5% [3].

## 3.2 Technical trends

Of the many current technical trends in data centers, four important developments with significant impacts on energy consumption will be discussed briefly in the following.

First, increasing miniaturization of IT components is bringing about increasing spatial density of processing power. Even today, 150 or more servers with two processors each can be placed in a single rack. However, the past has shown that the market for highly compact systems outside the area of high performance computing is developing only slowly. For example, despite the increase in performance density, total data center floor space in Germany has been increasing continuously, on average by approx. 3% per year [3].

A second important trend is the development of temperatures in data centers. They have increased significantly over the past ten years. As late as 2008, most data centers followed the rule that the temperature of incoming air was to be 18 to 20°C, whereas today, many data centers are operated with incoming air of 25°C or more. One major reason for this development is that ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) has significantly broadened the range of permissible temperatures in its recommendations for climate conditions. Temperatures of up to 27°C are recommended for incoming air for servers, but higher temperatures are also permissible. The higher temperatures enable significant efficiency improvements in climate control.

A third important trend is server performance, which is increasing on average. Increasing virtualization and concepts such as memory computing and big data result in powerful server systems with high processor performance and large amounts of working memory. Maximum power consumption of an average rack server increased from 270 watts in 2010 to just under 370 watts in 2015 [1]. Since the efficiency of servers in the partial-load range was improved at the same time, the average consumption of a typical rack server only increased from 153 to 185 watts. At the same time, the average load of rack servers increased from 10% in 2010 to 20% in 2015 [1], [13].

The fourth important trend to be mentioned is the increasing use of software systems for comprehensive data center management. They include both classical energy management solutions for the individual areas of a data center and increasingly also Data Center Infrastructure Management (DCIM) solutions. DCIM software solutions are available whose purpose is particularly to connect the IT universe with the data center infrastructure universe [14].

Here, we refer only briefly to further technical trends in data centers such as Converged Infrastructure or Software Defined Networks, Software Defined Storage, and Software Defined Data Centers. These trends are described in detail in the study for the German Ministry of Economic Affairs [1].

# 4 Energy consumption in data centers, broken down by types of energy consumers

The energy consumption of the various data center components in Germany was calculated for the years 2010 and 2015, and a trend forecast for the years 2020 and 2025 was prepared using the methodology presented above and taking the trends described in the previous section into account (Figure 1).

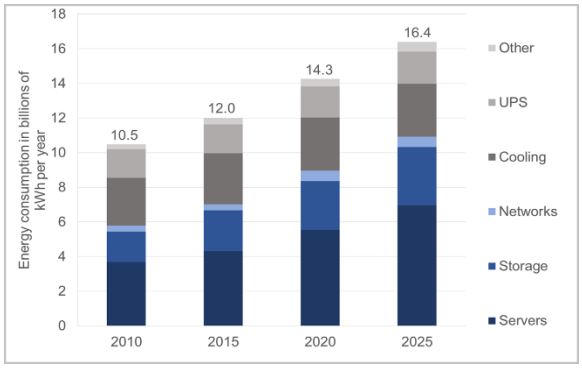



**Figure 1: Energy consumption of servers and data centers in Germany from 2010 to 2015 and forecast to 2025 (Source: [1])**

Although further efficiency gains were achieved in IT hardware and data center infrastructure, the electricity consumption of the data centers in Germany increased by 15% to 12 billion kilowatt-hours (kWh) in 2015. Increasing energy consumption by data centers is to be expected for the future, too. If the current trends in IT usage continue, German data centers' energy consumption will increase further and reach more than 14 billion kWh in 2020 and possibly even 16.4 billion kWh in 2025.

Although IT components' share of data center energy consumption is rising significantly, the share of infrastructure (cooling, uninterruptable power supply—UPS, etc.) still remains considerable. In 2025, one-third of the electricity required in data centers will presumably not be used by the IT components themselves, but by the infrastructure.

# 5 Structure of data centers and energy consumption

The developments described above have two important impacts in particular on the structure of energy consumption due to IT usage. Firstly, energy consumption is shifting away from end-user devices and toward data centers, as is processing power (Figure 2). This also results in increasing energy consumption by the telecommunication networks. Their share of IT energy consumption was approx. 5 billion kWh or approx. 15% in 2010, but is projected to rise to approx. 25% (8.6 billion kWh) by 2025.

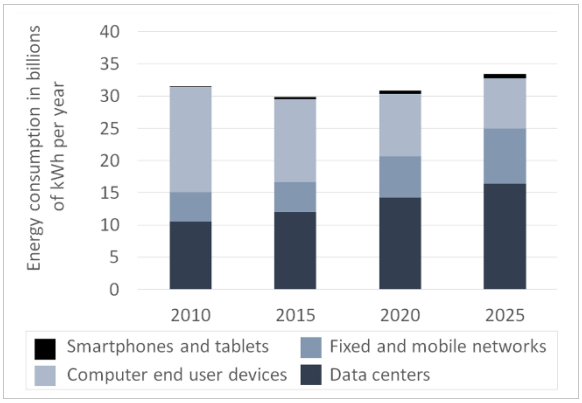
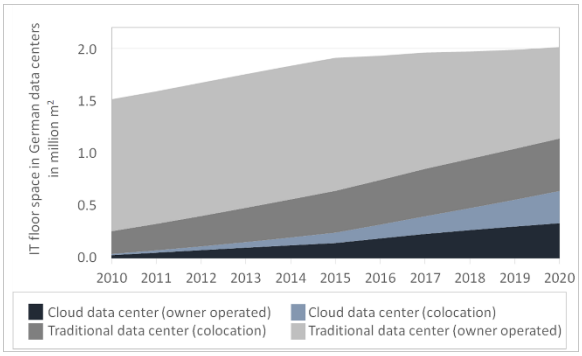



**Figure 2: Annual IT energy consumption in Germany in 2010, 2015 and forecasts for 2020 and 2025 (without TV and TV cable) (Source: [1]).**

A second important change in the structure of energy consumption is due to changes in the structure of data centers. The Delphi survey results were used to estimate the development of the structure of data centers in Germany over the next five years, differentiating between traditional data centers and cloud data centers. We also differentiated between in-house data centers and colocation data centers[1] (Figure 3). Cloud data centers are often operated on colocation space. The shares of cloud data centers and colocation data centers in Germany are increasing significantly overall. In 2020, approx. 40% of IT floor space in Germany will be in colocation data centers. Cloud services are provided on approx. one-third of IT floor space in Germany [9].




[1] Commercial providers rent out infrastructure capacity for outsourcing or situating servers in colocation data centers.

**Figure 3: IT floor space in German data centers by data center type**

This development impacts data centers' energy consumption. IT services can usually be provided more efficiently in cloud data centers in particular. One reason for this is that cloud computing can be provided with higher energy efficiency because of better capacity utilization, special hardware, and specifically adapted infrastructure [5]. In addition, cloud data centers are more modern on average and thus also more efficient than conventional data centers. Figure 4 shows that cloud data centers in Germany currently account for 13% of the IT floor space of all data centers, but only 9.8% of energy consumption. If this trend continues, the cloud data centers will take up approx. one-third of data center space in Germany in 2020, but only one-quarter of energy consumption.

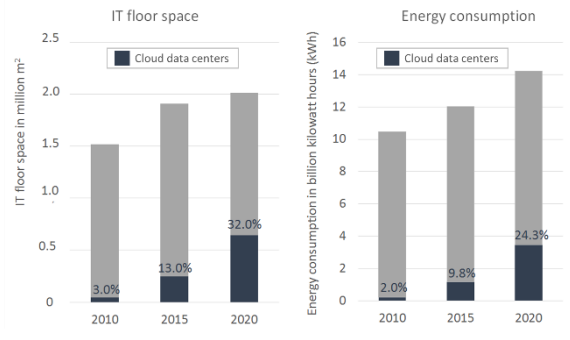



**Figure 4: IT floor space in German data centers by data center type**

In other words, efficient cloud data centers help to prevent energy consumption of data centers in Germany from increasing even more. Reductions of the energy consumption of data centers because of cloud computing are not to be expected, however.

IT operations in colocation data centers can often be more efficient than in small in-house data centers. Economies of scale, among other things, have positive effects here. But colocation data centers cannot optimize data center operations overall since ownership and responsibility for IT and infrastructure are in different hands [5]. It is assumed that energy consumption of the infrastructure in colocation data centers is somewhat lower on average than in in-house data centers. However, in particular large in-house data centers are often more efficient than colocation data centers.

# 6 Conclusions

Digitization and centralization of processing power mean that the energy consumption of data centers in Germany is continuing to increase—by 15% to 12 billion kWh between 2010 and 2025. Significantly increasing energy consumption by data centers is to be expected for the future as well—e.g., an increase to 16.4 billion kWh by 2025.

The trend toward cloud computing and the use of mobile end-user devices means that the energy consumption of telecommunication networks is also increasing significantly, from approx. 5 billion kWh in 2010 to a projected 8.6 billion kWh in 2025.

Although cloud data centers can be operated more efficiently than conventional ones, the efficiency gains overall are not large enough to reduce total energy consumption of data centers significantly.

# 7 Literature

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