Server stock data – A basis for determining the energy and resource requirements of data centres

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Abstract- **More and larger data centres are being built around the world. The rated electrical power of a single large data centre campus is often in the three-digit megawatt range nowadays. Such a data centre has the power consumption of a large city. But what is the total power consumption of all data centres worldwide? How high is the demand for other resources such as water and materials? And what future developments can be expected?**

A powerful and promising approach to answering these questions is the use of bottom-up models, which determine the energy and resource requirements based on the inventory figures of the devices and systems present in the data centres. Unfortunately, there is little available and reliable data on such inventory figures. This paper aims to make a contribution to reducing this lack of information. To this end, it focuses on the server equipment category, which clearly accounts for the highest proportion of the energy and resource requirements of data centres. Based on available information in scientific publications and data from market analysts, we estimate the total number of existing servers. We come to the conclusion that around 80 million servers will probably be in operation worldwide in 2024.

Keywords server, data centre, server stock, energy, resources

I. INTRODUCTION

The energy and resource requirements of data centres are increasing significantly. More and larger data centres are being built around the world to meet the increasing demand for computing and storage power resulting from digitalisation. In particular, the enormous opportunities offered by applications in the field of artificial intelligence will further support this trend. The International Energy Agency (IEA) estimates that the global electricity consumption of data centres could increase from 460 billion kWh to 590 to 1050 billion kWh in the period between 2022 and 2026 [1].

With growth rates like these, it is particularly important to have figures on the development of energy and resource requirements that are as reliable as possible. Unfortunately, previous studies on this topic have used different methodological approaches to arrive at sometimes significantly different results.

A particularly promising methodological approach for calculating reliable figures is the bottom-up approach. This approach is used to determine the energy and resource requirements of the devices and systems in the data centres on the basis of stock figures. However, little data is currently available on such device stock figures. Although there are market analysts who determine device sales figures, these are usually only made available for a fee. If they are purchased by research organisations, they are generally not allowed to be published.

This paper will use the example of the server device category to estimate how many servers are currently in operation worldwide. Focussing on the server category is expedient, as these are responsible for around 70 to 80 % of the electricity demand of IT devices [2], [3], [4], [5].

The server stock can be determined on the basis of sales figures and assumptions about average usage times. Unfortunately, the various market analysts sometimes calculate significantly different sales figures. For example, the sales figures for servers used for the 'Ecodesign Preparatory Study for Enterprise Servers and Data Equipment' in 2016 were so far apart, that a stock of between 8.3 million and 15 million servers was calculated in 2014 for an assumed useful life of four years at the time [6].

One reason for the uncertainty in determining sales figures for servers lies in the way they are calculated. Analysts' estimates are generally based on surveys of market participants. Unfortunately, the few large tech corporations that dominate the server market, the hyperscale cloud providers, are hardly willing to provide information about the servers they buy and operate, particularly for competitive reasons. The proportion of servers manufactured directly for hyperscale cloud providers - so-called ODM servers (original design manufacturer servers) - accounts for almost 50% of the entire server market [7].

Following a description of the methodology, an overview of the accessible market figures in scientific literature and from market analysts is provided below. The figures obtained are discussed with regard to criteria such as topicality, completeness and reliability. On the basis of this analysis, an estimate of the development of the worldwide server stock is made. The article concludes with a critical evaluation of the results and an outlook on open questions.

II. METHODOLOGY

This conference paper summarises the publicly available and freely accessible market figures on servers. The research for the market figures is based on the following two approaches.

Firstly, available data on the worldwide server stock will be determined on the basis of a literature search in scientific publications (Chapter III). It is expected that only little current information can be found in this way. This expectation is justified by the small number of publications on the energy

and resource requirements of data centres to date. In addition, the generally longer publication time of scientific articles means that the data is no longer up to date. Against this background, a lean systematic literature search is first carried out using the term "server stock" in Google Scholar. This makes it possible to estimate how promising this approach is. The search leads to 75 results. The analysis of the hits shows that only 17 publications deal with server stock in the sense of this publication. Only one publication mentioned data on the worldwide server stock. This is also the only one of the sources whose database is not older than five years.

As the approach of a systematic literature search does not appear to be very effective, the second research approach is to search the Internet for market research institutes that offer data on server sales. In almost all cases, these offers are subject to a charge. However, a number of market research companies also provide a - usually small - proportion of market data free of charge. Only data sets that provide information on server sales in the years 2018 to 2024 were used for this paper. Publications that appeared before 2021 were not taken into account. With this approach, seven data sets on the number of server sales and 15 data sets on revenue from server sales can be determined.

This summarised presentation of the available data on server sales and server stocks also includes considerations regarding the plausibility and reliability of the data. These considerations form the basis for an estimate of the current number of servers operated worldwide (Chapter IV).

One challenge when determining and analysing server inventory figures is the fact that there are a large number of different server types. In market analyses, server types are sometimes differentiated according to price class or CPU type. A more common distinction made according to price class differentiates between volume servers, mid-range servers and high-end servers. One difficulty with this differentiation is that a mainframe system can sometimes also be understood as a large number of individual servers. When differentiating by CPU type, a distinction is often made between x86 servers and other servers. More recent market analyses also include the category of ARM processors. As a lot of freely accessible data in particular does not differentiate between server types, only the total number of all servers is considered in this paper.

III. Results of the research

A. Scientific literature on server inventories

As already briefly described, the search for scientific articles on the topic of "server stock" yielded only a few results. 17 publications dealt with server stock in the sense of this paper. However, almost all of these publications were regionally limited, i.e. they only referred to the USA [9], [10] or Germany [11], for example. The datasets used are generally more than five years old. Only in one publication more recent data was found, that also referred to the worldwide server stock. This was a master's thesis at MIT from the year 2023 [8]. This thesis used server sales figures up to 2020 as a basis for forecasting developments up to 2030.

As the results of the literature research show, this approach is hardly suitable for determining reliable and up-to-date data on the current server stock. In addition to the publications found in the search for the term "server stock", the authors are aware of several other data sources on server stocks. In 2020, for example, Masanet et al. published an article in the journal Science [3] to which very detailed data on server stocks was provided as an appendix. The data differentiates server stocks according to different server types, in particular volume, mid-range and high-end servers. In addition, the server stocks in the various regions of the world are shown separately. The absolute number of server stocks is based on a Cisco white paper from 2018 [12]. It can be assumed that the Cisco figures are based on data from market analysts at the time. However, Cisco does not provide any further information on how the figures were determined. Unfortunately, the data sets are far too old to determine current developments in energy and resource requirements. A current publication on server stocks was published by the Borderstep Institute in 2023 [5]. This publication calculates the global server stock in the years 2015 to 2022 based on data purchased from the market research institute Digitimes.

To summarise, it can be stated that a literature search on scientific publications hardly seems suitable for determining reliable and up-to-date data on server inventories.

B. Data on shipments from market analysts

The search for data from market analysts on server shipments resulted in a total of seven data sets. Table I provides an overview of the data sets. The oldest data set is from the Market Intelligence & Consulting Institute from April 2021. Two data sets (Statista, TrendForce) are from the year 2024.

TABLE I. Market analyses of server sales (shipments)

Analyst	Date	Data available for the years*	Source	Remarks
TrendForce	Feb 2024	2019-2024	[14]	Source indicates shipments for 2024 and growth rates from 2020
Gartner	Jan 2023	2012-2022	[15]	Source lists Gartner figures until Q3 2022 - data is consistent with other published Gartner figures [16]
Aaron Rakers, Wells Fargo	Jan 2023	2020-2026	[15]	Source cites data from Aaren Rakers, Wells Fargo
Digitimes Research	Oct 2021	2019-2026	[7]	Data largely confirmed by data purchased from Borderstep in 2023
Omdia	Dec 2023	2022-2023	[17]	
Statista	Feb 2024	2018-2027	[18]	
MIC	Apr 2021	2015-2025	[19]	

* Only data from 2018 to 2024 was used for this publication.

Figure 1 shows the server shipments calculated by the various market analysts for the years 2019 to 2024. While the number of server shipments in 2018 is between 11.8 million and 15.2 million units, the range in 2024 is significantly larger and lies between 14 million and 20.7 million units. It is striking that Digitimes' figures are significantly higher than those of the other market analysts. Digitimes is a market analyst from Taiwan. According to Taiwan's Ministry of

Economic Affairs, 83% of the world's servers are produced in Taiwan [20]. Unlike other market analysts, whose analyses often refer to servers sold on the market, Digitimes' figures are based on the mainboards produced and sold. This has the advantage that the number of servers purchased directly from ODM manufacturers by hyperscale cloud companies in particular can be better estimated.

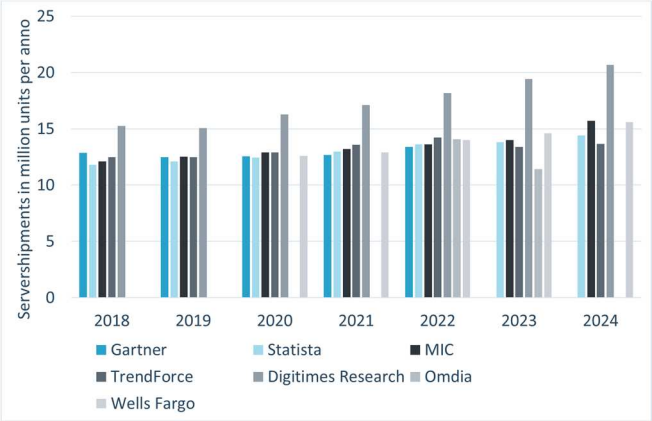

Fig. 1. Data on annual server sales (shipments) from various analysts for the years 2018 to 2024

C. *Data on market sales from market analysts*

Compared to the market data on server shipments, more sources were found for market turnover, totalling 15 data sets, which provide information on market development (Table II). Most of the sources provide market sales for the years 2022 and 2023. The oldest data set comes from " The Insight Partners" from 2022, eight data sets are from 2024.

TABLE II. MARKET ANALYSES OF SERVER SALES (TURNOVER)

Analyst	Date	Data available for the years*	Source
IDC	Feb 2024	2022-2025	[21]
GlobalData	Dec 2023	2022,2027	[22]
Gartner	Jan 2023	2023	[15]
Omdia	Dec 2023	2027	[17]
Statista	Feb 2024	2018-2028	[23]
Research and Markets	Nov 2023	2022,2028	[24]
Grand View Research	2023	2020-2023, 2030	[25]
Technavio	Jan 2024	2018, 2023, 2028	[26]
360 Market Updates	Mar 2024	2022, 2028	[27]
SkyQuest	Apr 2024	2022, 2023, 2031	[28]
Global Market Estimates	Mar 2024	2021, 2026	[29]
MMR	Feb 2024	2023, 2030	[30]
Market Research Future	Apr 2024	2022, 2023, 2032	[31]
The Insight Partners	2022	2022, 2030	[32]
MordorIntelligence	2023	2024, 2029	[33]

* Only data from 2018 to 2024 was used for this publication.

Figure 2 provides an overview of the sales volumes calculated by the various analysts for the server market. As with shipments, sales are also expected to grow. MordorIntelligence estimates market sales of around € 80 billion for 2024, while IDC expects over € 140 billion in the global server market.

Analysing the sales data does not allow any direct conclusions to be drawn about the server stock. However, the sales data can be used to determine the average market revenue per server and thus derive information on their performance. Unfortunately, only Statista and Gartner provide data on both market revenue and server shipments. This allows the average revenue per server to be determined. While Statista's average revenue for 2023 is around €6,000 per server, Gartner's average revenue is €9,500 per unit.

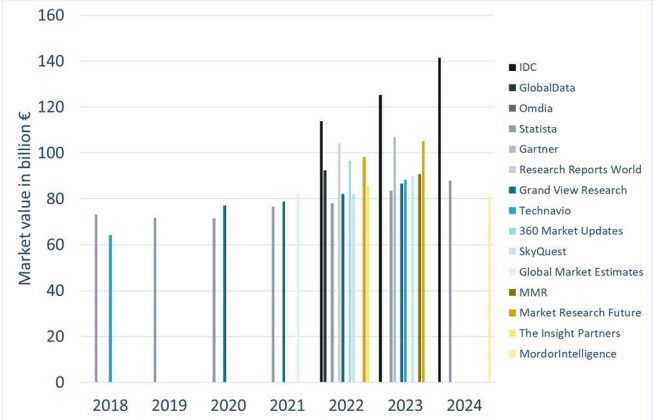

Fig. 2. Data on annual sales of servers from various analysts in the years 2018 to 2024 (exchange rate € 0.92 per US $ - as at 09/04/2024)

D. *Conclusions for the determination of server inventory figures*

As the above explanations have shown, it is - as expected - almost impossible to find up-to-date data on server stocks in the available scientific literature. One promising approach is to determine server stocks on the basis of the information on shipments provided by market analysts. Although the information provided by the individual analysts differs, the results of the research are nevertheless well suited for estimating the current server inventory.

IV. ESTIMATION OF THE WORLDWIDE SERVER INVENTORY

A. *Service life of servers*

To calculate the server stock on the basis of shipments, it is necessary to determine the average useful life of the servers. Different assumptions are made in the literature regarding the average useful life of servers. Volume servers are typically used for between three and seven years. Higher-quality mid-range or high-end servers are usually used for longer.

The Study on the Practical Application of the new Framework Methodology for Measuring the Environmental Impact of ICT from 2014 assumes an average useful life of 5 years for the calculations [34]. The Ecodesign Preparatory Study on Enterprise Servers and Data Equipment for an EU study from 2016 assumes an average useful life of four years [6]. A study for the German Ministry of Economic Affairs from 2015 assumes a useful life of 5 years for volume servers and 8 years for mid-range and high-end systems. In the recent past, the useful life of servers appears to have increased significantly, especially for large hyperscale cloud companies. Google, for example, is increasing the useful life of its servers to six years and Microsoft also operates its servers for six years. Meta has announced that it will operate its servers for

five years. At Amazon, it is assumed that the useful life of the servers is between five and six years [35]. As recently as 2020, these companies only operated their servers for three years.

Taking into account this extension of the useful life and the high share of hyperscale cloud companies in the global server market, it is plausible to assume that servers are currently used for between five and six years on average.

B. *Calculation of the worldwide server inventory*

Based on the above considerations, the global server inventory is estimated below on the basis of the server shipments determined. As the figures from the individual analysts differ significantly from one another and there is little reliable information on the average service life of the servers, three different estimates are made:

- *Lower estimate:* The lowest server sales figures are used for the lower estimate. The average useful life is assumed to be five years.
- *Average estimate:* The average estimate is based on the mean value of the available analyses of server sales figures. The average useful life is assumed to be 5.5 years.
- *Upper estimate:* The maximum server sales figures are used for the upper estimate. The average useful life is assumed to be six years.

The server sales figures shown in Figure 1 are used to calculate server stocks. As data from the years prior to 2018 is also required to determine the server stock in the years 2019 to 2023, this was calculated using extrapolation. For this purpose, the average market growth in the years 2018 to 2024 was used for the three different estimates. This average growth in server sales figures was 2.2% for the lower estimate, 3% for the middle estimate and 5.5% for the upper estimate.

Figure 3 shows the results of the estimate. In the lower estimate, the number of servers increased from 57.7 million to 63.3 million between 2019 and 2024. In the middle estimate, 68.8 million servers were in operation worldwide in 2019. This figure rises to 77.7 million in 2024. In the upper estimate, the number of servers increases from 84.1 million servers in 2019 to 106.7 million servers in 2024.

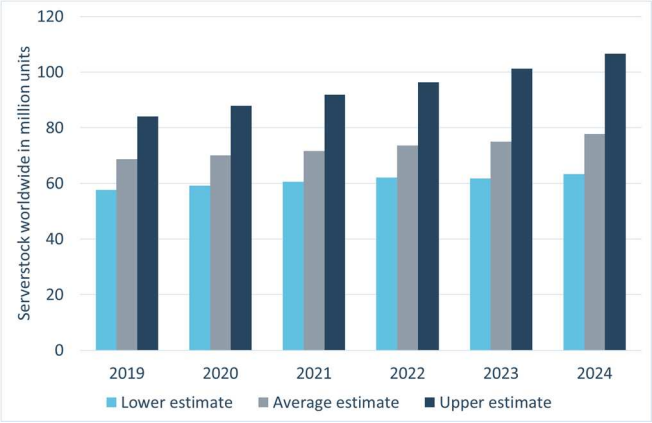

Fig. 3. Estimate of the global server stock in the years 2019 to 2027.

V. Discussion

As the above explanations show, it is difficult to determine the exact number of servers currently operated in data centres worldwide. Unfortunately, the figures on server stocks used in scientific publications to date are hardly suitable for current analyses. As a rule, these figures are based on market analyses that are significantly older than five years. Alternatively, data on server sales from market analysts can be used. However, this approach is also associated with challenges. There are various reasons for this. Firstly, different market analysts arrive at different results. Secondly, the calculation of inventory figures requires the average useful life of the servers to be determined. Here too, only estimates are available.

In order to deal with these challenges, this paper uses three different estimates to determine the number of servers. The lower estimate shows a global server stock of 63.3 million in 2024, the middle estimate 77.7 million and the upper estimate 106.7 million. The authors assume that the actual number of servers is close to the middle estimate. As it can be assumed that not all of the market analyses considered really cover all server sales, it is quite likely that there are currently even slightly more than 80 million servers in operation worldwide.

The results in this paper can be used for carrying out analyses of the energy and material requirements of servers worldwide. They can be regularly updated and supplemented on the basis of new available market data.

With the increasing use of artificial intelligence (AI), there is likely to be further differentiation in the types of servers and processors used in the future. In addition to traditional x86 processors, servers based on ARM processors are already increasingly being used for AI applications. Furthermore, the computing power of AI hardware is mainly provided by graphics processing units (GPUs) or tensor processing units (TPUs). In future, this development will make it even more difficult to determine a meaningful figure for server stocks and will also pose new challenges for analyses of the energy and material requirements of data centres.

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