Verband der deutschen Internetwirtschaft e. V.

Evaluation of efficient computer centers in Germany

eco – Association of the German Internet Industry e.V.

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1 Introduction

The eco – Association of the German Internet Industry e.V. study group Data Center evaluated the efficiency of the computer centers in Germany during the period of March to August, 2008.
eco (www.eco.de) has been the Internet industry association for over ten years in Germany. More than 400 member enterprises employ more than 300,000 people and have a turnover of approx. 75 billion Euros yearly. About 230 backbones of the German Internet are represented in the eco association. The aim of the association is to promote the commercial use of the Internet to strengthen the position of Germany in the Internet industry and with it Germany as a business location. The eco association sees its activities in protecting the interests of the German Internet industry in politics, in the legislative process and in international committees.

Within the scope of the study group Data Center an online evaluation was carried out which evaluated data of a total of 49 computer centers with a total area of approx. 50,000 m² and an available capacity of approx. 30,000 kW. The purpose was on one hand to understand the state of the computer centers in Germany and on the other hand to introduce a benchmark system to those responsible in all industry areas of IT, and finally, to show which measures are suitable to increase the efficiency and which measures may not lead to the desired results.
The current efficiency of computer centers in Germany was determined in the form of the PUE factor. Moreover, the different factors which could possibly have an influence on the efficiency as for example the type of the air conditioning technology, the tier classification of the computer center or the use of enclosure were examined.

2 Definitions

Before an online evaluation can happen, it is necessary to define some principal terms in detail.

Definition computer center

A computer center is at least a self supporting, structurally separate area with accessible air conditioning control, accessible electricity supply, an **Uninterruptible Power Supply (UPS)**– (quality electricity leveled, excess voltage protection, etc.) set up with a five-minute bridging structure period for shutting down the operating systems, facilities for fire detection (smoke sensors) and for firefighting (fire extinguisher), with minimum physical access protection and stable network connection (a provider, an independent network supply.)

Tier Classification

The tier classification according to Uptime Institute divides the computer centers into four classes (The Uptime Institute, 2008). A simple level I computer center has non-redundant building components and an individual non-redundant distribution networks which supply the servers of the location.

A level II computer center has redundant building components and an individual non-redundant distribution networks which supply the servers of the location.

A level III computer center has redundant building components and multiple distribution networks which supply the servers of the location. Basically only one distribution network supplies the server at all times.

A level IV computer center is finally a defect tolerant computer center which has redundant building components and multiple distribution networks which simultaneously supply the servers of the location. All servers are supplied with electricity in two ways and are installed in such a way that they are compatible with the system of the location.

Definition IT

Any components which are connected to the UPS thus, for example, server, storage, network equipment, telecommunication equipment, but also emergency lighting, UPS secure control systems etc. are summarized into this study under the term "IT".

3 Methodology

To gain access to data from as many computer centers as possible, an anonymous online questionnaire (eco e.V., 2008) was provided. The questionnaire was provided by a sub study group of the study group Data Center of eco e.V. within the scope of several meetings. All together four big computer center operators as well as an employee of the eco association and an independent consultant were involved in the making. The questionnaire is divided into six categories:

- General questions
- Measurements and values
- Spatial measures
- Location of the computer center
- Electricity supply
- Air conditioning, air conditioning technology & air circulation

It was possible to skip individual questions, if an answer of a special question was either not possible or not wanted. With the exception of the question about the type of the computer center only one answer was allowed for every question respectively. Thereafter the results were evaluated quantitatively and qualitatively.

Special focus was given to the calculation of the Power Usage Efficiency (PUE).
In the course of the past two years this developed into a quasi standard for the measurement of the energy efficiency of computer centers (The Green Grid, 2007). The Power Usage Efficiency factor is calculated by dividing the total power demand of a computer center by the energy which is made available for the IT. A PUE of 1.0 would mean that the total energy which is required for the computer center is available exclusively for the IT. However, the value of 1.0 is merely a theoretical value, as in the best possible case energy is required for the components which cannot be assigned to the IT, e.g. by UPS heat loss or lighting.

The Environmental Protection Agency (EPA) is expecting based the current trend an average PUE of 1.9 for 2011 (EPA, 2007.) For 2011, the EPA expects a PUE of 1.3 for best practice and a PUE of 1.2 for state of the art. The computer centers of Google Inc are used currently as an industry benchmark and they already achieve a PUE factor of 1.21 annually in its six big computer centers (Google Inc, 2008) today.

In the questionnaire two options to record the computer centers’ power demand were offered: one by providing the kWh over a year and the other by providing the current consumption in KW.

To record the PUEs, the values received from the question: „Which average electrical workload do you take off of the local electricity provider? “, were divided for the evaluation by the values, which were received from the question „Which average electrical work do you provide to the IT? “. With the division, the data „kWh per year“and „alternative kW“, become directly comparable. For the evaluation, the power demand for efficiency increases was subtracted from the average electrical work at local energy provider.

Hence we arrive at the following formula:

$$PUE\ acc.\ to\ eco = \frac{Total\ Energydemand - Energydemand\ \ for\ the\ increase\ of\ \ Efficiency}{Energydemand\ \ for\ \ IT}$$

In other words this means: the PUE is calculated from the average, annual electrical work measured at the discharge point of the local EVU (energy supply company) less the electrical work which is used for the increase of efficiency (e.g., by heat reclamation), divided by the required electrical work for the IT.

This applies as long as the provided electric power for the efficiency increase does not exceed the savings.

4 Results

The evaluation of 49 questionnaires showed, fortunately, a PUE value for computer centers in Germany quite satisfactory in international terms. However, clear weak points – were also detected; above all concerning data compilation by the individual computer center operators.

4.1 Descriptive results

Altogether, as mentioned already at the beginning, computer center areas with a total area of 49.727 m^2 were recorded. The smallest computer center recorded has a total surface of 95 m^2, the biggest one a total surface of 10,000 m^2. The average height from the raised floor is 2.81 m and the average raised floor height is 51 cm.

The total energy consumption of the recorded computer centers (CC) amounts to approx. 240 GWh per year which corresponds to 2.4 % of the power demand of all computer centers in Germany.

25 % of the recorded computer centers correspond to the tier classification I,
27 % to the classification II, 29 % to classification III and 19 % to the classification IV.

Currently only 33 % of all computer center operators have staff which deal with the subject of energy efficiency and at least even 37.5 % of the computer center operators get by without a responsible office who keeps track of the current costs for the IT in the computer center.

31.25 % of all computer center operators still work without a separate computer center budget.

Among the recorded computer centers, 50 % are used for several purposes and
50 % are used for exclusively for business. 27 % of the exclusive computer centers are used exclusively for internal IT (ERP (Enterprise Resource Planning), materials management etc.), 8 % exclusively for hosting (dedicated server, application hosting, webhosting) and 2 % exclusively for HPC (High Performance Computing).

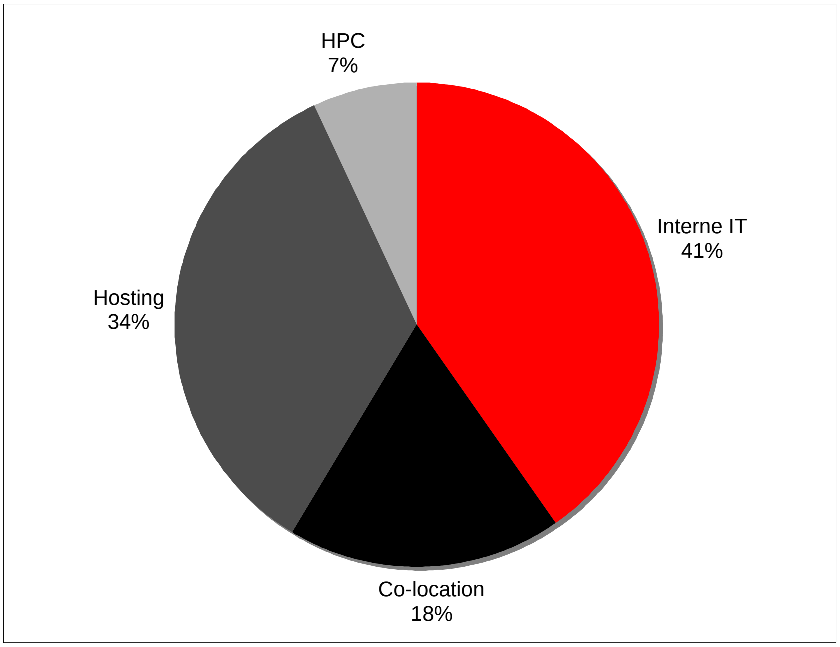

Illustration 1: Type and purpose of all evaluated computer centers

Finally 55 % of all questioned computer center operators use shutters for the separation of airflow and also many of the rows are built according to the cold and warm aisle principle. Only one computer center operator uses a logical cold flow enclosure, two operators separate the airflow by a warm flow enclosure.

The average temperature and air humidity in the computer centers are as follows:

Description	**Temperature in °C**
Temperature in the CC area	22 °C
Minimum intake temperature	17 °C
Maximum permissible intake temperature	24 °C

Table 1: Temperature in the computer center

Description	Rel. air humidity in %
Average air humidity	37 %
Minimum air humidity	26 %
Maximum permissible air humidity	49 %

Table 2: Air humidity in the computer center

4.2 Power Usage Efficiency (PUE)

At 13 of the 49 computer centers it was possible to calculate the PUE based on valid information. Two of the 49 computer centers (4 %) had already implemented measures for the increase of the efficiency using waste heat. On average the PUE of the computer centers lies at 1.62 which seems to be a very good value – above all in comparison with the USA (EPA, 2007) and compared internationally. The most efficient computer center showed a PUE of 1.17 and the most ineffective one of 2.21. Two computer centers which already use heat recovery performed a PUE of 1.42 and 1.62, respectively. In the following chart, the values are given in detail:

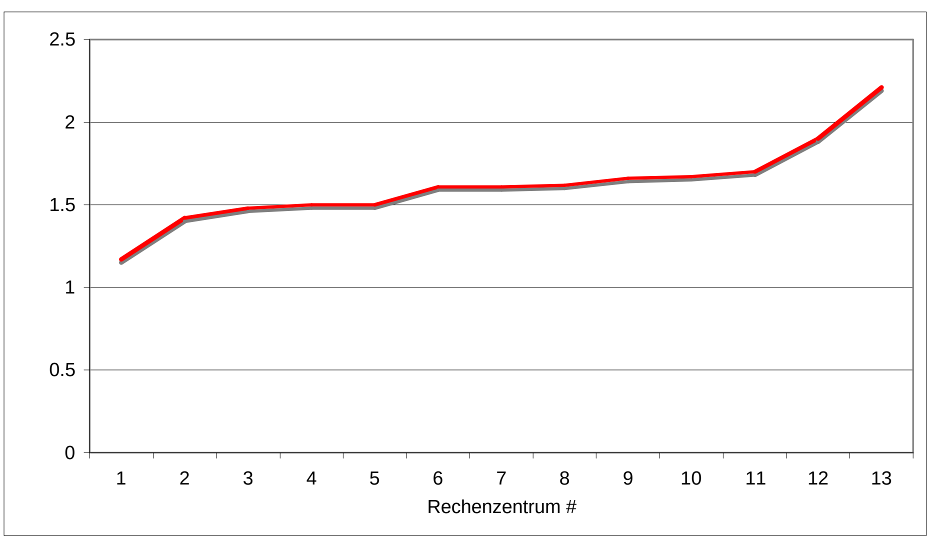

Illustration 2: PUE of the evaluated computer centers given by the values increasing

In the following chart the PUE values are displayed in a table:

PUE	1.17	1.42	1.48	1.50	1.50	1.61	1.61	1.62	1.66	1.67	1.70	1.90	2.21
CC	1	2	3	4	5	6	7	8	9	10	11	12	13

Table 3: PUE of the individual computer centers increasing

It is remarkable that the PUE at the computer centers which carried out the calculation on the basis of kWh – i.e. which measure the PUE over the whole year, are better by around 0.15 (average of 1.55 compared to an average of 1.70) than the computer centers which have shown their current consumption in KW. This difference seems to be due to the differences in temperature at the time of the measurement. Thus the annual average temperature in Germany amounts to 7.6 °C which lies 3.2°C below the average temperature of the months of April, May and June (DIN-German Institute for Standardization, 2003).

The lowest PUE meaning the highest efficiency comes from a computer center with the tier classification one. Can we then generally assume that a higher tier classification entails a necessarily worse PUE?

4.3 PUE Dependence on Tier Classification

In many discussions the reason for bad efficiency is pointed to the elected tier factor, with the argument that the higher the tier classification, the worse the efficiency. This could not be proved in the present study. There was no significant correlation between the tier classification and the PUE (r =.18; p =.563).

Detailed data are as follows:

Tier Classification	I	II	III	IV
Average (A)	1.17	1.79	1.72	1.59
Standard deviation (SD)	0.16	0.27	0.07	0.24
Random test (N)	1	2	6	4

Table 4: Tier Classification in relation to PUE

The statistical evaluation proved no significant differences between the individual tier classifications which can be due, however, also to the limited random test. Hence, the individual results were qualitatively analyzed.

The increase of the PUE from tier I to tier II is easily explain despite the small random test, because with tier I (see tier classification) no component is redundant. Subsequently a tier II must be more ineffective. With tier III only the paths are laid out redundantly in the computer center. A second network replacement infrastructure or two power sub-distributions in the computer center should have little effect on the efficiency, hence, it is also not surprising that the average PUE of tier II and tier III are not significantly different. However, the better PUE with a tier IV computer center is surprising, because according to general definition all components must be doubled up. Consequently such a computer center cannot be more efficient than a class III computer center.

Mathematically this can be proven as follows: If one assumes a number in components (N) greater than one (e.g., 2), with any efficiency smaller than one (e.g., 0.9), for a tier III computer center (N+1 redundancy) we arrive at:

0,9*0,9*0,9 = 0,729; however, for tier IV the redundancy must also be N, i.e.: 0,9*0,9*0,9*0,9 = 0,656. 0,656 <0,729, hence, tier IV is always more inefficient than tier III, if N> 1.

Why does the study not reflect this result?

A wrong classification of the computer centers cannot be the cause for it, because with the exception of one participant everybody gave suitable answers to the question about tier IV concerning the redundancy of the network replacement infrastructure and UPS. Even if you change the classification of the wrongly classified computer center for the same calculation, the efficiency of the tier IV computer centers would still be slightly better / nearly the same as the efficiency of the tier III computer centers (1.63 for tier III in comparison to 1.62 for tier IV), but in no case worse. As the only, sensible reason for the result can be that other factors apparently have a far higher effect on the efficiency than the tier classification and consequently there is no significant difference in practice, even if it would have to exist purely for the sake of computation. At this point we would point to the average temperature in the computer center, because the higher the tier classification, the higher the temperature in the computer center (r =.515; p =.041).

4.4 PUE dependence on the used air-conditioning technology / air conditioning system

In contrast to the tier classification it is obvious that the used air conditioning technology has a direct effect on the efficiency of the computer center and both correlate with each other significantly (r =.65; p =.031):

- Average PUE for direct evaporator = 1.63
- Average PUE for central cold water production = 1.94
- Average PUE for indirect free cooling system = 1.50
- Average PUE for combined air circulation and cold water systems = 1.57

With the help of the average values it can be found quite clearly which air conditioning technology is most efficient, namely the indirect free cooling. This is simply explicable if one relates the functionality of the individual air conditioning systems to the annual average temperature in Germany of 7.6 °C (DIN-German Institute for Standardization, 2003).

4.5 PUE and other building-technical circumstances

Within the scope of the study even other data of the computer centers were questioned, e.g., raised floor height, floor, insertion of cold aisle or warm aisle- enclosure etc. In the following table, have been displayed which other factors have an influence on the PUE:

Question	Correlation with the PUE (r)	2-sided significance (p)	Is a correlation recognizable?
Total area of the computer center	-.37	.326	No
Height of the raised floor	.39	.237	No
Radiation of sun rays on the building in %	-.33	.315	No
Floor of the computer center	.02	.956	No
Average temperature in the computer center	.43	.186	Low
Average air humidity	-.13	.698	No
Volumes of the data wiring under the raised floor	.35	.294	No
Location of the computer center in Germany	.37	.268	No

Table 5: Relationship between PUE and other values

To sum up, we can say that an efficiency increase cannot be reached by exclusively concentrating on one individual criterion alone. Consequently, it is important to study many details to achieve a good efficiency in the computer center as a whole.

This is already a current practice with many computer center operators as the data material shows. There is a direct correlation between the insertion of shutters and the sealing of the gaps and between the servers and the construction of the servers in cold and warm aisles.

Both measures are seen as efficiency-increasing methods, hence, it is not a surprise, if these measures are used either in combination or not at all.

Cold / warm aisles				
Insertion of shutters		Yes	No	Total
	Yes	10	1	11
	No	1	8	9
	Total	11	9	20

Table 6: Correlation between the insertion of shutters and cold / warm aisles

5 Discussion

The PUE was at the time of the study the only really international benchmark. However, as indicated in the study as well, there are some problems with this efficiency indicator which originate on the one hand from the type of the calculation of the PUE, on the other hand, however, which are also caused by the existing structure in computer centers:

- Random measurement versus measurement over time
- Consideration of the recovery of the energy in the calculation of the PUE
- Disregard of the consideration of the total efficiency

5.1 Random measurement versus measurement over time

PUE does not define unambiguously for which period a measurement should be carried out. As a consequence the value can be influenced in either direction by the selection of a certain time frame.

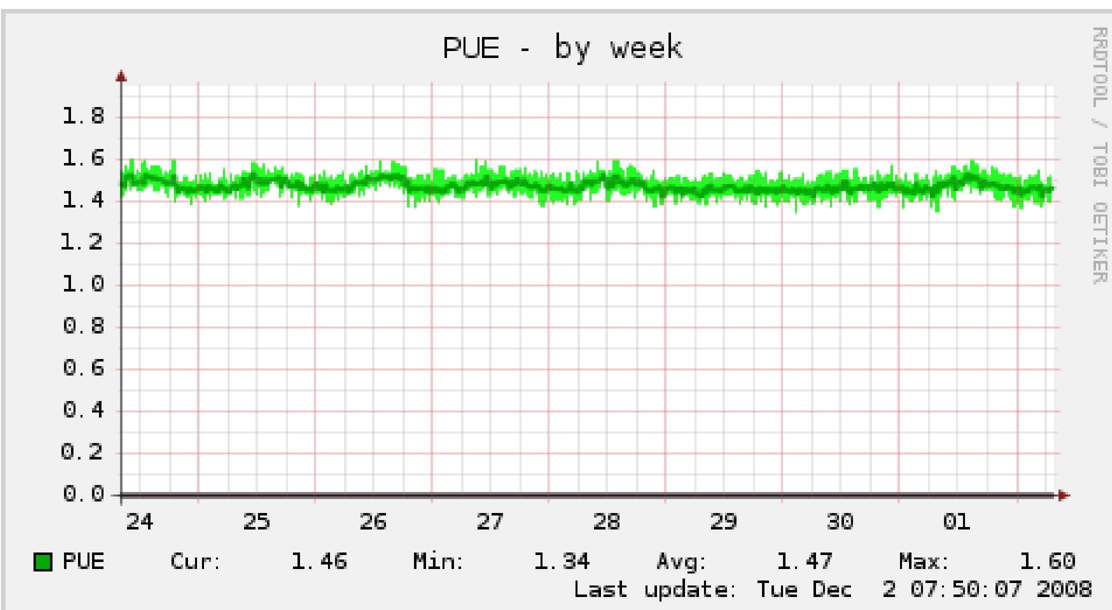

Illustration 3: PUE progress within one week

As is evident from the illustration, the PUE factor of the displayed computer center varied within only one week (from 11.24.08 to 12.2.2008) by up to.26 (MIN 1.34; MAX. 1.60). Consequently one should see PUE data very critically which do not exactly specify whether they were calculated based on time measurement or on the basis of the past 12 months. However, this statement does not question the validity of this study, because it was shown that computer centers with an annual measurement are more efficient than computer centers with a selective measurement. Moreover, the measurements were carried out during exceptionally warm months for the annual comparison, which is why they present a rather too bad picture of the computer center scenery in Germany, than a too good one.

It was striking that only 13 out of 49 computer centers had generally the possibility to show correct values. It was also possible for the computer centers which could give the power consumption figures to also make the remaining data available for the questionnaire. Here there seems to be a very big deficit for the people responsible for the computer centers, because apparently only a low percentage of them carry out really specific, regular measurements. This was also confirmed by the fact that less than half of the computer center operators can name responsible employees for the energy costs and efficiency of the computer centers. A visualization of the actual condition should be the first, important task for all operators. Nowadays there are simple solutions and open source solutions which should also fit in the smallest budgets. Besides, it would suffice in the beginning to determine merely the total power demand. This could happen, for example, by recording the current power bill every month. In addition, the possibility of recording the power demand of the UPS should be discussed with the UPS manufacturers.

5.2 Influence of heat reclamation on the PUE

Especially in big computer centers an important challenge is the heat recovery for further increase of efficiency. Here, the problem of the calculation of PUE often arises after the installation of a heat recovery. The values of an evaluated computer center should explain this in an example.

The computer center has a total power demand of 960 kW, out of this 540 kW are available for the IT. Consequently the PUE is: 960 / 540=1,78.

Now, however, a total of 86 kW are used out of 960 kW for heat recovery (heating of a big office building), therefore, the PUE would actually be: (960-86)/540=1,62.

However, on the other hand, the operator "saves" only 40 kW in energy, i.e. if it would not reclaim the heat, then the total power demand would be for the computer center plus office buildings approx. 1000 kW. Out of this arises a third, likely PUE: (960-40)/540:1,70.

Now which is the correctly calculated PUE? A lot speaks for the second option, a PUE of 1.62. The 86 kW which are used are independent from the operation of the computer center and serve a completely different purpose, in this example, heating of business premises.

5.3 Disregard of the consideration of the total efficiency

Within the scope of the study it has been discovered that by only considering the computer center and the quotient PUE, two important factors are completely disregarded.

One of them is the efficiency of the IT. Are all servers operated in the computer center necessary or is double energy saving possible by consolidation and virtualization? A switched off server saves because it saves not only on the energy which it needs, but, e.g., also on the energy necessary for the cooling.

On the other hand, when considering efficiency total power demand must always be taken into account.

An example should briefly explain this. If one operates a computer center with a total power of 150 kW out of which 100 kW is reserved for the IT, the PUE amounts to 1.5. Now the intake temperature is increased up to the highest limit allowed from the current 22 °C (for the three biggest server manufacturers this corresponds to an intake temperature of 32 °C for the servers). Hereby a power demand arises for the IT of 120 kW (Dell Inc, 2008). Therefore, with a PUE of 1.5 a new total power of 180 kW is required. Consequently, by trying to save one has achieved exactly the opposite!

6 Summary

The German computer centers are positioned already very well by international standards. To be able to continue to meet the international standards, in the future as well, however, it is necessary when building new computer centers to consistently take into consideration energy efficiency and to continuously examine the connection and compatibility between different components which could have a positive or negative influence on the energy efficiency. Only this way can the current technological edge present in some areas be maintained long term.

An exchange of information among the individual computer center operators and a uniform data collection is at any rate important, so that the results which should lead to increased energy efficiency can be compared objectively with each other. Only in this manner it is possible to avoid bad investments for supposed energy savings methods and to lower the actual energy consumption.

In this sense, the introduction of respective measurement points at the computer centers would be sensible. Above all the manufacturers are called on to provide easy, reasonable and sensible solutions.

In spite of all criticism it can be said in general that the PUE is still a good instrument for the evaluation of the current efficiency situation of a computer center, especially if it is used as a measuring tool among others. However, to be able to use the PUE as an objective criterion to measure energy efficiency, it is necessary to establish some parameters beforehand to guarantee a comparability of the results. This cannot happen at this point and remains a desideratum for the near future.

7 Literature

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